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COLOR VISION IN INFANTS[1]

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HISTORICAL AND THEORETICAL INTRODUCTION

Color vision in adults has been very extensively investigated. The facts of color mixing, of color contrast, of range of color vision, and of color blindness have been well established upon the adult level. There have been many color theories based upon the mass of evidence which has been obtained. The first which received widespread attention was that of Thomas Young in 1807, and since then many more have followed.

From the evidence that has been produced so far in researches upon color vision in infants, hope has been expressed by numerous authors that such investigations would produce evidence as to the truth or falsity of certain color theories which take a developmental viewpoint toward color vision, notably the theories of Schenck and of Ladd-Franklin. Both of these theories state that the first stage of development

[1] Grateful acknowledgment is expressed to Dr. John E. Anderson, to Dr. Florence L. Goodenough, and to Dr. Miles A. Tinker for many helpful suggestions and criticisms during the course of the investigation. The writer is grateful for the facilities made available to him by the Institute of Child Welfare of the University of Minnesota for carrying out this research. He is also greatly indebted to Mrs. Eleanor Hammond, Superintendent of the Harriet Walker Maternity Hospital of Minneapolis, for the opportunity to carry out the experiment at that institution.

is when gray breaks up into yellow and blue, and the second is when yellow breaks up into red and green. None of the studies upon infants have been able to show such an order of development. However, the possibility is present that studies of color vision in infants will throw some light upon the developmental order of color vision if it can be demonstrated that a development in color vision does occur in infancy. If no developmental order exists the proof of the adequacy of developmental theories will necessarily rest upon other sources of evidence.

The problem of the nature of color vision in children first arose in 1877 when Darwin, from observations upon his own children, concluded that color vision in children is a rather late chronological development. However, there is a notable lack of knowledge concerning the color vision of very young infants. So far, certain evidence merely suggests that they have color vision. There has been no direct evidence that very young infants can discriminate between colors, due to the fact that suitable methods for investigating the problem have been lacking.

In attempts to determine the differentiation of colors by children and by infants, the following methods of investigation have been used:

A. Methods involving language responses

1. Showing colors to the child and asking him to name each in turn
2. Teaching the child the color names and recording the length of time required to learn them
3. Asking child to give name of favorite color

B. Methods not involving language responses

1. Grasping
2. Matching samples of colored wools or papers
3. Selection of a color named by someone
4. Presenting a number of colors to the subject and asking him to indicate the one he prefers
5. Following with the eyes
6. Fixation of eyes

7. Recording of bodily activity when a color stimulus is presented
8. Conditioning

A thorough review of the investigations endeavoring to determine the nature and extent of color vision in infants has been given by Staples.[2]

It has been claimed that infants have 'sensations' of color as early as three months, although the average judgments as to when infants first can surely distinguish the various colors is around five or six months for most investigators. Most of the early investigators stated that children fail to 'perceive' or to 'distinguish' colors until the end of the second year, and some claimed that it was as late as three or four years of age. There is no consistence in the order in which the various colors are claimed to be first perceived or sensed by children.

It becomes quite evident after a brief perusal of the results of different investigators that a critical evaluation of the methods of determining color vision in infants is necessary in order to understand the divergent results which have been obtained, and in order to arrive at some conclusion as to what is an adequate method for investigating the problem. First of all, it is quite obvious that the methods which involve language are not applicable to very young infants. Among the various non-language methods which have been used, the question must be considered as to whether they are suitable to be used to produce accurate results with the youngest infants.

Grasping a colored paper upon a colored or a gray background of the same intensity is an adequate test of whether the infant can differentiate between the various colors, but the youngest infants do not reach or grasp.

Matching samples of colored paper or wools is obviously applicable only to children who have reached the stage of development when they can understand and carry out directions given to them verbally. The same is true of asking a child to pick out a color named by someone or of presenting

[2] Staples, R. Color vision and color preferences in infancy and childhood, *Psychol. Bull.*, 1931, **28**, 297–308.

a number of colors to the child and asking him to indicate the one he prefers.

Conditioning the child to react to one color and not to others will demonstrate adequately the discriminating power which a child possesses for distinguishing between the various colors when they are presented simultaneously, either in pairs or in multiples, providing they are equated in intensity so that conditioning does not take place upon that basis. This is a possible technique to apply to the youngest infants but conditioning presents many difficulties of a technical nature, so that a simpler technique which will give reliable and valid results is a preferable means of investigation.

Recording the amount of bodily activity to the different colors or even combinations of colors presented together suffers from the defect that there is no simple criterion from which interpretations can be drawn as to whether the infant is discriminating between colors.

Measuring the length of time of fixation of the eyes upon one of two colors when they are presented simultaneously upon a neutral gray background is a color preference method which has produced successful results with older infants but not with very young ones.

Parsons [3] says of the results from studies based upon color preference, "We cannot, of course, infer from the absence of color preference between two colors the absence of any difference in sensation; but from evidence showing that one color is markedly preferred to another we can infer that the colors are sensed as different colors, unless the preference can be ascribed to differences in brightness."

Following a moving color stimulus with the eyes is a method of investigation which can be applied to even the youngest infants. McGinnis [4] has shown that records of eye movements corresponding with a moving stimulus can be obtained in infants as early as two weeks after birth, and he observed eye movements of a newborn infant in correspondence to a moving stimulus. It is, therefore, a simple

[3] Parsons, J. H., *Colour Vision*, Cambridge University Press, 1915, p. 156.

[4] McGinnis, J. N., Eye-movements and optic nystagmus in early infancy, *Genet. Psychol. Monog.*, 1930, **8**, 321–430.

motor response which may be used as a criterion of whether the infant can discriminate between colors, providing certain experimental conditions are observed.

The only investigator up to the present time who has attempted to study color vision of infants by watching the eye movements in relation to a moving color stimulus is Marsden.[5] Two colored cards were held before the child's eyes and then moved slowly apart, and the card which the infant's eyes followed was noted. Only one child was studied. Blue, green, yellow, black, red, white, brown and newspaper were the stimuli; and each color was paired with every other color. Although the following of the eyes was used, the results of the investigation depended upon the preference shown by the infant in following one of the two stimuli presented. Newspaper was more popular than any of the colors.

Several experimental conditions must be observed when eye movements in relation to a moving color stimulus are used as a criterion of the extent of color vision in infants. First, the dependence of the results upon the child's color preference must be eliminated. They must be forced to make a differentiation between colors if they are capable of so doing. Second, the colors must be equated in intensity so that if the infants respond it will be on the basis of color and not of intensity.

The present experiment will describe the results of using a technique which takes into account these factors in studying the infants' eye movements as an indication of whether or not they differentiate between colors.

For our problem of determining whether or not infants have color vision there are three lines of evidence which must be established and which we know hold for normal color seeing adults. First, it must be determined, on an anatomical basis, at which age the rods and cones are fully developed in the retina, since these are the end organs for visual sensations. Second, it must be determined whether the cones and rods are both functionally distinct. Third, after the two factors given

[5] Marsden, R. E., A study of the early color sense, *Psychol. Rev.*, 1903, **10**, 37–47, 297–300.

above have been established, the extent of the ability to distinguish the different colors one from another must be determined. The anatomical basis is determined through histological studies of the retina. The independent functioning of the rods and cones is determined by the existence of the Purkinje phenomenon. The different colors which can be seen is determined by finding out whether the infant can differentiate between two or more colors presented at the same time, when intensity differences between them are controlled as a factor which might influence the differentiation.

Considering now the anatomical basis for color vision, Mann [6] states that by the seventh fœtal month the retina has assumed practically the adult arrangement and proportions. At this stage the nuclei of the rods and cones have none of their primitive oval shape. They are all differentiated. She states that the last cells to develop are probably the nuclei of the rods and by the seventh fœtal month the visual path is complete and capable of functioning, although perfect vision is not possible because the macula is far from perfect at this age. From the eighth fœtal month to the fourth month after birth she designates as the period of macular differentiation proper. During this period, the nuclear and bipolar layers thin out, and the cone nuclei increase in number, the cones themselves become highly specialized, and the *fovea externa* develops in consequence. She further states that, at birth, the cone layer in the fovea is one row deep, and the cones do not as yet appear longer than those in the paracentral region. This explains, she thinks, the lack of power of central fixation. The final development appears to depend upon the stimulus of light. By sixteen weeks after birth, the cone nuclei in the macular region have increased to three rows deep. In addition, the cones in the fovea have increased in length so that a curve appearing as a depression can be recognized in the external limiting membrane. Thus we see that, although perfect form discrimination is probably not possible until some time after birth, both rod and cone vision are possible for a month or two before birth.

[6] Mann, I. C., *The Development of the Human Eye*, Cambridge University Press, 1928, pp. 68–151.

The Purkinje shift in relative brightness values of colors from photopic values for light adaptation to scotopic values for dark adaptation demonstrates functioning cone vision. Individuals with congenitally monochromatic vision lack this shift and have only values which correspond to scotopic values for normals. If the shift can be demonstrated in infants, functioning cone vision can be assumed. Peiper [7] has shown that the Purkinje phenomenon occurs in infants. He obtained it for two premature infants of about two and three months of age respectively. He had previously discovered that an eye-neck reflex could be elicited from infants when they were held in an upright position and a light flashed just above the level of their eyes. His technique employed red, yellow, green and blue *Tscherningschen Gläserkastens* color filters, and the *Tscherningschen Gläser* series of neutral filters to vary their intensities. The light source was a nitrogen lamp. He determined the minimum intensity for the colors which was necessary to call forth the reflex. He found the order of relative stimulus values for the light adapted eye of the infant, ranging from least amount of white light necessary to the greatest, to be as follows: yellow, red, green, and blue. He then dark adapted their eyes for an hour and repeated the procedure. He found that under this condition the relative order of stimulus value to be: blue, green, yellow, and red. Although he had only two infants with whom he tried the dark adaptation experiment, he repeated it upon each of them several times to obtain both the photopic values and the scotopic values. He found photopic values for the colors he used for six infants, repeating his observations upon each several times. This experiment shows clearly, that both photopic luminosity values and scotopic luminosity values can be obtained in infants.

An important fact to be obtained from Peiper's results is that the photopic brightness values for the colors he used were the same for both the adult and the infant. This fact makes the practice of equating different colors on the photopic luminosity scale of values the correct procedure to follow to

[7] Peiper, A., Ueber die Helligkeits und Farbenempfindungen der Frühgeburten, *Arch. f. Kinderheilk.*, 1926, 80, 1–20.

eliminate the possibility of discrimination on the basis of brightness. Only the infant with a congenital color-deficiency might make discriminations on the basis of brightness by using these values, because the relative values for such cases do not fall upon the photopic luminosity scale of normal color seeing individuals.

Peiper says that his results do not preclude the possibility that infants may have colorless sensations from color stimuli such as exist in the periphery of the retina in normal color vision.

The question concerning the color vision of infants resolves itself, then, to discovering whether they can discriminate between colors, or whether color stimuli arouse colorless light sensations such as are present in the periphery of the retina in normal color seeing individuals. We have considerable evidence that infants do see the various colors by five or six months of age. Staples [8] presented each of four colors simultaneously with a gray of equal brightness to three months old babies. She found that each was looked at for a greater number of seconds than was the gray. The total figures for the colors and for gray showed significant differences in favor of color. The rank of the colors, according to seconds looked at, was yellow, blue, red, green, but the differences were not statistically significant. She found that infants between six and twenty-four months were unequally responsive to the different colors. Red was the most effective stimulus, followed by yellow, blue and green. No one has been able to actually demonstrate by any of the methods so far used that color vision is present below three months of age.

The following experiment will attempt to show that color discrimination is present in infants as young as fifteen days of age.

Method, Apparatus and Subjects

There are two requirements for a method to determine the extent of color vision in very young infants. First, the method must depend upon a simple reaction which all infants will be able to make. Second, the stimulating situation must be such that the

[8] Staples, R., The responses of infants to color, *J. Exper. Psychol.*, 1932, 15, 119–141.

reaction obtained can be interpreted as having been brought about through color discrimination by the infant.

All normal infants will follow moving objects with their eyes from birth. This is, then the simplest reaction to utilize in examining color vision. A situation must be devised which will stimulate moving of the eyes only if the infant is able to discriminate between colors. Two colors must be presented simultaneously. In order to be sure that the infant must respond to color to make the discrimination between the two, they must be perceptually equal in brightness. Peiper's work [9] discussed above shows that infants have the same relative photopic luminosity values for colors that normal color seeing adults have. The colors must be equated, therefore, upon photopic values for daylight adaptation to assure equal intensities for the infants. The two colors presented must be arranged so that one can be moved while the other remains stationary. If the infant can discriminate between the two colors which have been equated for brightness he will see the moving color and will watch it move. The present experiment has attempted to fulfill the requirements outlined above.

For the color stimuli Wratten monochromatic filters, manufactured by the Eastman Kodak Company, were selected. The catalogue numbers of the filters used in this experiment are 71A, 73, 74, and 75. The color names of the filters given in the catalogue will be employed in future reference to them. They are for 71A, red, for 73, yellow-green, for 74, green, and for 75, blue-green. The letter symbols, R for red, YG for yellow-green, G for green, and BG for blue-green, will be used.

The neutral tint series of Wratten filters were used to equate the brightness of the color filters. The modal length of each filter is different.[10] Only one filter (YG) permits any large amount of nonconsecutive groups of wave lengths to pass. These monochromatic filters allow the narrowest transmission of wave lengths of all obtainable filters.

The source of light for the filters was obtained from a 500 Watt Tungsten Concentrated Filament lamp placed in a Delineascope projection machine, shown in Fig. 1*A*. An ordinary house fan, Fig. 1*B*, was used to cool the lamp. A water cell, Fig. 1*C*, was used to filter the infra-red rays in order to protect the filters from becoming overheated.

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[9] Peiper, A., *op. cit.*

[10] The modal wave length of a filter is the one which has the highest transmission value. They are, for red, 640 $\mu\mu$, for yellow-green, 570 $\mu\mu$, for green, 530 $\mu\mu$, and for blue-green, 490 $\mu\mu$. The maximum discrimination sensibility for hue, *i.e.*, the smallest differences in color tone, occurs at about 497 $\mu\mu$, and at about 585 $\mu\mu$. There are two other maxima, one at about 435 $\mu\mu$, and the other at about 636 $\mu\mu$. The minima occur at about 454 $\mu\mu$, 535 $\mu\mu$, and 624 $\mu\mu$. The values are not exactly the same from one observer to another, but the regions of the spectrum in which they occur for different observers are the same. Parsons, J. H., *op. cit.*, pp. 30–32.

The red, yellow-green and blue-green filters correspond closely in wave length, then, to points of maximum discrimination, and the green filter to one of the points of minimum discrimination. The color theories consider the points of maximum discrimination sensibility as the fundamental colors. The Young-Helmholtz followers accept as the fundamental three component colors, ones which occur near the maximum in the red, yellow-green, and blue-green. Ladd-Franklin, in her developmental theory, claims the maximum sensitivity in the yellow-green and the blue-green is evidence that they are more primitive colors than the others.

The filters were not equal in brightness value, so a correction was necessary to the difference between them imperceptible. The measurement of the brightness of the light transmitted by each filter was made with a Westinghouse light meter which embodies the Westinghouse Photox cell. The color response of the photox cell for wave lengths of visible light compares very closely to the sensitivity of the average eye. To avoid sudden fluctuations in the current, the measurements for each filter were made at night when the electric current was not being used in any other part of the building where the measurements were being made. A uniform flow of light was obtained from the lamp throughout the measuring period.

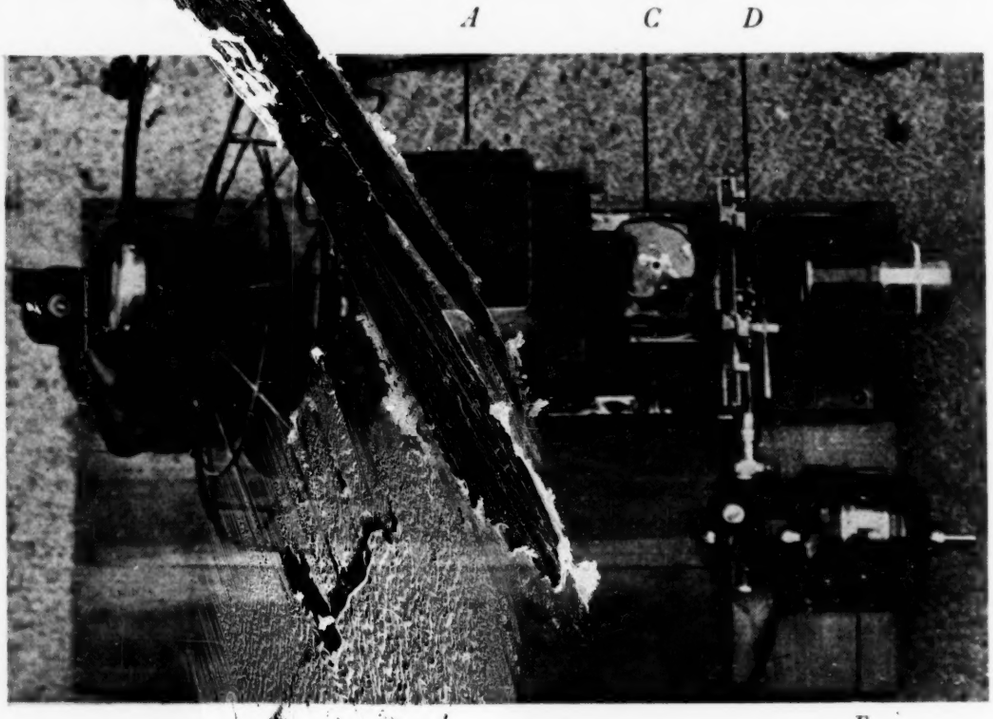

FIG. 1. Projection apparatus and apparatus for moving color filters.

The cell of the light meter was set upon the plane of the objective lenses of the projection machine, approximately 7 inches from them, with the light focused directly upon the cell. All of the measurements were made with the cell in the same position so as to avoid any error which would result by moving it even slightly. Each measurement was checked three times in order to insure accuracy of the light value for each color filter. It was found that the same values could be obtained by successive measurements for the different color filters.

It was found that the relative luminosity values for the color filters with 100 as the standard of comparison were 100 for G, 69 for YG, 50 for BG, and 42 for R. YG and G were combined with neutral filters of 50 percent transmission value. BG was combined with a plain gelatin dummy filter. Now the relative values become 100 for G, 86 for BG, 80 for R, and 73 for YG. The maximum difference in brightness was 27 percent. However, on the level of brightness used, it was thought that this difference would not be perceptible.

In order to determine whether or not it was, two plain filters, one BG and one neutral tint filter, were used in which the moving stimulus was a difference in brightness

instead of a difference in color. The brightness differences were obtained in the following manner.

The value for BG without adding a dummy filter in the second scale of values given above was 96. When three plain gelatin dummy filters were added to BG the resulting value was 73. With the value of BG taken as 100, the resulting value obtained by adding the 3 dummy filters was 76. A combination which contained a 24 percent difference in brightness value at the level used could then be made. Only one color combination, G and YG, had a greater brightness difference and this was but 3 percent more.

In a similar manner the neutral tint brightness filter was obtained. By combining two neutral tint filters of 6.3 percent and 32 percent transmission values, respectively, a relative value of 91, in the second scale of values above, was obtained. By adding 3 dummy filters with these a value of 70 was obtained. Taking the value of the gray as 100, the resulting value was 75. Thus, a second combination could be made which contained a 25 percent difference in brightness at the level used. This difference was but 2 percent less than the maximum occurring between G and YG. When these brightness filters were projected upon the screen, no difference in brightness between the center and the outside was noticeable, either for the BG filter or the neutral tint filter.

The next procedure was to combine the color filters in such a form that they could be projected upon a screen placed above the infant so that one color would be in the center of the screen, completely surrounded by another color. Each filter was a 2 inch square gelatin filter. A sharp ticket punch was employed to punch out a clean center piece of one filter, which was carefully saved, and the same procedure was repeated with a filter of another color. The center piece of the first filter was then placed in the hole in the second filter, and vice versa. The punched piece was one-eighth of an inch wide and three-sixteenths of an inch long. The filters were mounted with Canada Balsam between two 2 inch square pieces of lantern slide glass of the best crystal grade.

Table 1 gives the color combinations with their relative brightness values, the brighter of the two colors being indicated as 100, and it also includes the two brightness filters. BG was combined with a dummy filter for its pairing with R only. The

TABLE 1

COLOR AND BRIGHTNESS COMBINATIONS WITH THEIR RELATIVE BRIGHTNESS VALUES

Outside Color	Brightness Value	Center Color	Brightness Value
Red	100	Yellow-Green	92
Red	80	Green	100
Red	92	Blue-Green	100
Yellow-Green	92	Red	100
Yellow-Green	73	Green	100
Yellow-Green	76	Blue-Green	100
Green	100	Red	92
Green	100	Yellow-Green	73
Green	100	Blue-Green	96
Blue-Green	100	Red	92
Blue-Green	96	Green	100
Blue-Green	100	Blue-Green	76
Gray	100	Gray	75

filter with the yellow-green outside color and the blue-green center color was never successfully constructed for use and had to be omitted from the series.

When the filters were placed in the projection machine and sharply focused on the screen, the line which separated the center from the outside filter showed as an outline. The outline could be practically eliminated by throwing the image on the screen

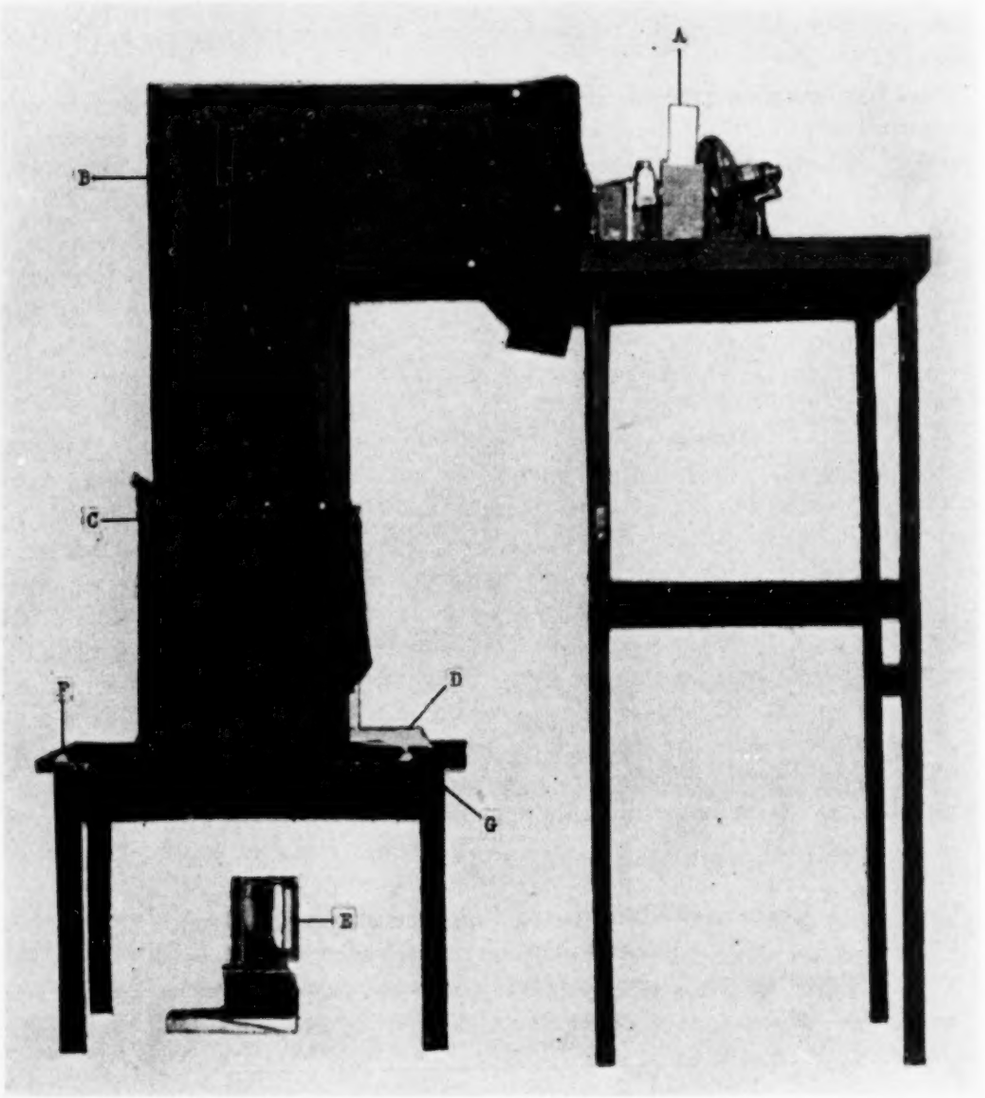

FIG. 2. Set up for complete apparatus.

slightly out of focus. The center and the outside color then appeared to fuse into one another with no line of demarcation.

In order to test whether the infants might be following the fused outline, a red filter was made replacing a center of the same instead of another color. This was then used in the same manner as the other filters as a control to determine the effects, if any, of the mechanical construction of them.

The filters were placed in the filter holder of the projection machine, Fig. 1*D*, which was on a tall stand, Fig. 2*A*. The colors were projected upon a large plate glass

mirror, Fig. 2*B*, placed two feet from the objective lenses on a 45 degree angle. The mirror reflected the colors upon a translucent colorless paper screen, Fig. 2*C*, 24 inches by 17½ inches, which was two feet away. The magnification was 24 times, so that the center color on the screen was 3 inches by 4.5 inches. All of the filter was not used for projection at any one time. It therefore could be moved back and forth in the projection machine, keeping the screen always flooded with color. Thus, the center color alone appeared to move because the outside color never went off the screen. The resulting effect was that the center color appeared to move within the field of the other color.

An experimental situation, therefore, was established in which, if the infant was able to discriminate between colors, the movement of the center could be seen. If he could not discriminate between colors, no movement would be apparent.

The filter holder, Fig. 1*D*, was moved back and forth on a small track. A small Bodine variable speed motor, Fig. 1*E*, with a 35-1 reduction gear, wired in series with a 250 ohm rheostat, to vary its speed, was used as a driving force. A level winding gear was attached to the drive shaft being in turn attached to the filter holder by a reducing lever. The pinion of the reducing lever could be changed to reduce or increase the extent of the backward or forward motion of the filter holder. The reducing lever was adjusted to move the center color back and forth eighteen inches across the screen.

The infant to be tested was placed on his back upon a platform, Fig. 2*D*. His head was held in position so that his eyes were directly under the center color in its stationary position on the screen. A simple device, adjustable to the infant's head, held it still so that eye movements could be observed without the complication of frequent turning of the infant's head to obscure them. When the infant was in this position, it was about fifteen inches from his eyes to the screen directly above.

The whole housing of the structure, built on top of an ordinary table, as shown in Fig. 2, was made of Masonite board. The dimensions of it were built to conform to the measurements of the screen. A heavy curtain over the opening at the top fitted tightly around the objective lenses of the projection machine and served to keep out any extraneous light. The light emanating from the projection machine was the only light which reached the screen. Two sides of the compartment in which the baby was placed were of the Masonite material. One end was covered with a large piece of cardboard with a small observation opening near the top. The other end was hung with heavy black cambric to serve as a curtain. The child was thus cut off from outside light and disturbances when he was in the compartment.

When observing the infant's reactions to the moving stimulus the observer stood at the head of the table looking through the observation opening in the cardboard screen. He held his head in such a position that the moving stimulus and the infant's eyes could be watched simultaneously.

The experimental procedure was the following. The colors were projected upon the screen with the center color in the center of the screen. The baby was then laid upon the platform. His head was clamped into position and the curtain was lowered. A control period of one minute allowed the experimenter to observe the eye-movements of the baby while the stimulus was stationary in order to later contrast them to eye-movements in relation to the moving stimulus. At the end of the control period, the experimenter started the color moving. He then carefully watched for following of the infant's eyes in relation to the moving stimulus.

The length of the observation period was set for five minutes at the beginning of the experiment. It was found, however, that it was not necessary to hold to the full length of the period for all infants. Following of the stimulus, sufficient to show the

presence of color discrimination, occurred early in the period in most cases. When no following could be observed, the infant was dismissed at the end of five minutes. All children were observed for at least one minute.

The period of observation was five minutes for each of the three control filters. When no observation could be made because of crying or sleepiness, the infant was dismissed at the end of one minute. In some cases, it was possible to make observations while the infant was crying or was sleepy, as will be indicated later.

The criterion for judging whether or not the infant followed the moving stimulus during the experimental period was as follows. If at any time during the period the infant definitely followed the moving stimulus at the same rate at which it was moving it was counted as following.

The experimenter had to adjust the speed of the moving stimulus to the rate at which the infant could follow best in order to determine more accurately whether the eye-movements were moving in relation to the stimulus. Each infant seemed to have a rate at which he could best follow, and the rate of movement could be quickly adjusted to that rate at each observation.

The experiment was made with 24 infants, 13 girls and 11 boys, at the Harriet Walker Maternity Hospital in Minneapolis. They ranged in age from 15 days to 70 days on the first day they participated in the experiment. The average age was 43 days. The group was divided into three experimental groups. The first had 8 babies, the second, 12 babies, and the third, 9 babies, 5 of them continuing from the second experimental group and 4 of them new.

Each infant in the group being tested was observed each day of the experiment. One filter combination per day was presented to each infant.

With the third experimental group of 9 babies a second observer [11] observed simultaneously with the experimenter in order to test the reliability of obtaining judgments of following under the experimental conditions employed. He observed the baby from the foot of the table while the experimenter observed from his accustomed stand at the head of the table. Each observer made his judgments of when the infant was following the moving stimulus independently of the other. The observer at the foot of the table pushed the button provided at that end, Fig. 2*G*, when he noted a period of following, and the observer at the head of the table did likewise, a button being placed at his end of the table, Fig. 2*F*. The degree of correspondence of judgment could then be determined by the number of concurrent marks upon a polygraph record, Fig. 2*E*.

The second observer and the experimenter observed together for 53 observation periods. In 41 of these periods the experimenter judged that the infant followed the moving stimulus. The second observer agreed with the experimenter in judging that the infant followed the stimulus in the same 41 periods. In only one observation period did the second observer judge that the infant followed when the experimenter did not, and there were no such instances when the experimenter judged that the infant followed when the second observer did not. Since this is the basis upon which the results are presented below, it shows that the method of making judgments is one where high agreement between two observers can be obtained.

To further show the reliability of the method used, the following computations show that two observers can agree upon specific 'periods of following' during observation periods. When the infant followed the stimulus across the screen without interruption, either with one long pursuit movement of the eyes or with saccadic movements, it was counted as a 'period of following,' or, if at any time in its course across the screen,

[11] Mr. E. Donald Sisson.

the infant followed the moving stimulus in definitely separated intervals, each such interval was also considered a 'period of following.' The total number of 'periods of following' recorded by the second observer was 327, and by the experimenter, 365. The two records corresponded 249 times. The experimenter agreed with the second observer upon 75 percent of the latter's judgments, and the second observer agreed with 68 percent of the experimenter's judgments.

Results

Tables 2, 3, and 4 give the complete results from the observations upon the infants. The first and second groups had two opportunities to observe each color combination. Since there was but one filter which had the YG and BG combination, this filter was used twice in the experimental series. There were but two children who did not respond by following all color combinations, both failing to follow the filters with the YG and G combination due to crying each time they were presented.

Summarizing the results, excluding infants W through Z, 100 percent of the children responded to the R and G com-

TABLE 2

Results from First Experimental Group

Infant	Sex	Age in Days at Start of Experiment	Responses of Infants																
			Colors in Order of Presentation	Outside Color	R	YG	R	R	YG	BG	G	BG	YG	G	G	YG	R	Gr	BG
				Inside Color	G	G	BG	YG	BG	G	YG	R	R	BG	R	BG	R	25% Darker	24% Darker
			No. of Days Increase in Age		0	1	2	4	5	6	7	8	9	11	13	14	15	16	16
A*	M	70			F†	F	F	F	F	F	F	F	F	F	F	F	N	N	
B	F	68			F	C	C	F	F	F	F	F	F	F	F	F	N	N	
C	F	67			F	C	F	F	C	C-F	C	C-F	C-F	F	C-F	F	C-N	C-N	
D	F	66			F	C	F	F	N	F	F	F	F	F	F	F	N	N	
E	F	64			F	F	F	F	F	F	F	F	F	F	F	F	C-N		C-N
F	F	56			F	F	F	F	F	F	F	F	F	F	F	F	N		N
G	F	54			F	F	F	F	F	C	F	F	F	F	F	F	N		N
H	F	53			F	C-F	F	F	C	C	F	F	F	F	F	F	N		N

* Premature infant.

† Explanation of symbols: F, following; C, crying, fussing, or fretting, no following; N, no response; C–F, crying, fussing, or fretting, but with eyes open and following; C–N, crying, fussing, or fretting, but with eyes open and no following; S–F, sleepy, but occasional awakenings with following.

TABLE 3

RESULTS FROM SECOND EXPERIMENTAL GROUP

Infant	Sex	Age in Days at Start of Experiment	Responses of Infants														
			Colors in Order of Presentation	Outside Color	YG	R	R	YG	R	G	YG	G	G	BG	BG	YG	R	BG
				Inside Color	G	BG	G	BG	YG	BG	R	R	YG	R	G	BG	R	24% Darker
			No. of Days Increase in Age		0	2	3	4	5	7	9	10	11	12	14	16	17	18
J	M	25			F*	F	C-F	C	F	F	C-F	F	F	F	C	F	C-N	C
K	M	19			C	F	F	C-F	F	F	S	S	F	S	F	F	N	N
L	M	27			C	S	C-F	C-F	C	F	F	F	C	F	F	F	C-N	C
M	F	33			C	C	C-F	C	N	C-F	F	F	F	C-F	S	C-F	C-N	N
N	M	35			F	C-F	F	F	C	C-F	F	F	F	F	F	F	N	N
O	M	40			C-F	F	C-F	C	C-F	F	F	C-F	F	C-F	S	F	C	N
P	F	43			F	C-F	F	F	F	F	F	F	F	C-F	F	C-F	C-N	N
Q	F	45			C	C	C-F	C-F	C	C-F	C-F	F	C	C-F	C	F	C-N	N
R	M	47			F	F	F	C-F	F	F	C-F	F	F	F	F	F	N	N
T	M	55			C	C	F	C-F	C-F	F	F	F	S-F	F	F	F	N	N
U	M	57			S	C-F	F	C-F	F	F	F	S-F	F	F	F	C-F	N	C
V	M	17			F	C-F	S-F	F	F	F	F	F	C	F	C	C-F	C	N

* For explanation of symbols see Table 2.

TABLE 4

RESULTS FROM THIRD EXPERIMENTAL GROUP

Infant	Sex	Age in Days at Start of Experiment	Responses of Infants							
			Colors in Order of Presentation	Outside Color	R	BG	G	G	G	YG
				Inside Color	YG	R	YG	R	BG	BG
			No. of Days Increase in Age		0	2	4	5	6	7
K	M	38			F*	F	F	F	F	F
R	M	66			C	C	N	F	N	F
T	M	74			F	F	F	F	C-F	F
U	M	76			N	F	F	F	F	F
V	M	36			F	F	F	F	F	F
W	F	15			F	F	F	F	C	C-F
X	F	26			C	S-F	C-F	S	F	F
Y	M	22			C	S	F	F	F	F
Z	F	21			C	F	C	C-F	F	C

* For explanation of symbols see Table 2.

bination; 100 percent to the R and YG combination; 100 percent to the R and BG combination; 90 percent to the YG and G combination; 100 percent to the YG and BG combination; and 100 percent to the G and BG combination. None of the children responded either to the red control filter, the neutral tint filter with the 25 percent darker spot in the center, or to the BG filter with the 24 percent darker spot in the center. Four of the eight babies in the first experimental group were presented with the neutral tint filter. The remaining were tested with the BG filter. With these control filters the movement upon the screen was almost imperceptible and was not sufficient to attract the infant's attention. Throughout each period the experimenter and a second observer watched carefully to detect any following but observed no response in any case. It is, therefore, evident that the difference in color of the color combination filters was the factor which attracted the infant's attention to the moving filter.

All of the cases where no response to color combinations are indicated in Tables 2, 3, and 4 can be accounted for by the fact that the infant's attention was not centered upon the moving stimulus. For example, Baby E's eyes were fixed upon the observer's eyes at the observation opening throughout both the control and the experimental period when the YG-BG and BG-R combinations were presented to her. The observer tried to overcome this difficulty by putting a piece of paper over the opening and moving it aside just enough to permit him to make his observations. This was fairly successful but she would suddenly stop following the moving stimulus on other occasions to look up toward the opening, and if the observer's eyes were there she would fixate upon them every time.

Baby M's failure to react to the R-YG combination was due to the fact that she was quite active on that day and had slipped down upon the platform so that her head was out of position and not centered under the screen. The moving stimulus was beyond the top of her head where she could not see it. The experimenter attempted to place her

back into position but she commenced to cry and had to be dismissed.

In the third experimental group the introduction of a second observer who looked through the side of the curtain at the foot was a distraction to Baby R on presentation of the G-YG and the G-BG combinations, and to Baby U on the presentation of the R-YG combination. Their eyes were focused upon him and never were centered upon the screen above.

Conclusion

It has been demonstrated in this experiment that infants are able to discriminate between colors employed, as evidenced by the fact that they followed the movement of each color within the field of the others. They were not making the discrimination upon the basis of a brightness difference or of some mechanical aspect of the experimental situation. This was shown by the use of adequately controlled situations involving only these conditions, and no following occurred.

The present experimental conditions were not designed to discover hereditary color-blindness, but were devised solely to demonstrate whether or not the young infant's color vision is dyschromatopic, as is the periphery of the adult's retina, where normal photopic values for color hold, although no color sense is aroused under ordinary conditions. When congenital color blindness occurs, the relative luminosity values for daylight adaptation do not conform to those for normal color vision. A congenitally color-blind infant, therefore, being tested under the experimental conditions used in this experiment, might be able to follow the moving stimulus on the basis of a difference in intensity. Since only 8 percent of males and 1 percent of females are classed as dichromats, with 11 males and 13 female infant subjects in this experiment, the chances of obtaining in this group even one dichromat would be very small. The chances of having a total monochromat would be exceedingly small indeed, and the chance of having a blue-blind infant would still be very much smaller. The chance that all 24 infants would have one or

another of these congenitally color-blind conditions is practically impossible. Because of this, it is possible to assume that probably all of the infants used in this experiment had normal color vision.

It therefore follows, in conclusion, that the infants used in this experiment, except for the rare possibility of a congenitally color-blind infant, were discriminating between red and yellow-green, red and green, red and blue-green, yellow-green and blue-green, and green and blue-green.

Summary

1. Two facts were already known which suggested that very young infants had color vision. They were the anatomical presence of rods and cones and the experimental demonstration of the functioning of the cones as distinct from the functioning of the rods. It was pointed out that neither of these facts could be relied upon as proof of color vision until it could be shown that infants were able to make discriminations between differences in wave length. It was further pointed out that the methods which had been employed in the investigation of color vision in infants had been so far unsuccessful in showing whether the very young infant could make such discriminations. The present experiment attempted to arrive at an answer to this question.

2. The ability of 24 infants between 15 and 70 days of age, at the beginning of experimentation with them, to discriminate between combinations of red, yellow-green, green, and blue-green was studied.

3. Wratten monochromatic filters equated so that there were no perceptible differences in intensity were used to produce the colors.

4. Combinations of the color filters were made up so that two colors were projected upon a screen above the infant's head as he lay on his back. It was then determined whether the infant could detect movement when the filter was moved back and forth in the projection machine. The appearance on the screen of the two colors was such that one color was surrounded by the other color. When the filter was moved,

the center color appeared to move within the field of the other color. If movement could be detected discrimination between the two colors by the infant could be assumed.

5. By observing the following of the infants' eyes in relation to the moving color stimuli, it was found that they could discriminate between the color combinations red and yellow-green, red and green, red and blue-green, yellow-green and green, yellow-green and blue-green, and green and blue-green.

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MAZE LEARNING WITH KNOWLEDGE OF PATTERN SIMILARITY

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We sought in this experiment to discover in part the influence of understanding upon maze learning in so far as its effects can be revealed and studied in terms of the number of trials necessary for learning, the number of blind alleys entered during learning, the number of times each blind alley is entered during learning, and the sequence or order of alley elimination. One maze pattern was used with fifteen male subjects. Each individual learned this pattern (maze 1) when the maze was so placed that the side with the starting position was directly ahead of him and at right angles to his dorso-ventral axis. Following learning under these specific spatial conditions, the maze was then rotated in a clockwise direction, as around a central point, so that the starting position now lay slightly to the left of the original place. This rotation, which moved the starting and goal positions over arcs of 90° or distances approximately equal to three inches, caused pattern II to have a 'new' starting position as well as a 'new' goal position, as far as spatial relations to the subject were concerned. After it had been again learned in this position (II), the maze was rotated successively to positions of 180° (III) and 270° (IV), at each of which places it was again learned. At the close of our experiment, we had accordingly secured four different sets of learning data from each subject upon a single maze pattern which had been rotated as a unit, thereby moving the starting and goal points over arcs of 90°, 180°, and 270° and over distances approximately equal to 3, 6, and 9 inches from their original positions. All four learning tasks (0°, 90°, 180°, 270°) were completed at one sitting.

The factor of understanding was quite specific. The

individual was told that his task concerned the learning of one maze pattern four different times. He was told that after he had learned it at one position, the maze would be turned 90° in a clockwise direction so as to give another learning position.[1] To make this point quite clear, the experimenter rotated a piece of paper before the subject. No other information was given him. He was never permitted to see the maze. During learning, the subject sat behind a screen through which his right arm was advanced. A sleeve was fitted over this hole in order to prevent any possibility of his seeing. Three trials without any blind alley entrance were accepted as the criterion of mastery. Following each period of learning, the subject was asked to sit at an adjoining table and carefully draw a diagram of the maze pattern from start to goal and to indicate upon it as well as he was able both place and direction of each blind alley. The subject was then required to go through the maze once more, before it had been rotated to a new learning position, in order to report verbally upon the location of each blind alley. The subject was instructed to avoid alley entrances but to report specifically concerning each alley as he came to it. It is assumed that the drawing provided a basis for a quantitative statement of recall and that the verbal report, given while the subject moved through the maze, furnished factual data upon amount of recognition. If one wishes, the drawing and the verbal report may possibly be considered respectively as being 'recall outside a maze' and 'recall inside a maze.' We have simply regarded the latter as representing one form of tactual and kinæsthetic recognition. It reveals what the individual, while traveling a familiar course, is able to report concerning the way in which he must move in order to avoid entering blind alleys. The data from the drawing and verbal report have enabled us to compare recall and recognition with respect to amount and accuracy of each as well as to those changes which occur with repeated learning of a single pattern. They have also enabled us to relate recall and recognition to

[1] We have previously reported upon learning under these conditions with the exception that the individual was not told about rotation. See Human learning with a rotated maze, *J. Psychol.* 1936, 1, p. 280.

frequency of alley entrances. We have been aided, moreover, in a study of certain other problems such as (1) the persistence of particular alleys and the order of their elimination throughout the series of four learning tasks, (2) the significance of the position of each alley within the maze pattern itself for frequency of entrance and order of elimination, (3) the spatial relation of each alley to the *learner* in terms of its relative difficulty as measured by frequency of entrance and by firstness and lastness of elimination, and, finally, (4) the specificity of the total maze pattern as a learned unit in so far as it is revealed by disruption which follows the spatial shift involved in rotating the maze over arcs of 3 inches.

Data and Discussion

The quantitative results which we obtained from 15 subjects are shown in Table I in terms of the total number of trials required to master each of the four learning tasks (0°, 90°, 180°, 270°). An examination of these data immediately reveals the relative decline in difficulty that marks the learning of mazes II, III, and IV. The percentages of decline for these three positions, as based upon maze I, are 59, 70, and 82.

TABLE I

Total Number of Trials Required by Each Subject to Learn a Single Maze Four Different Times

Subject	Maze I	Maze II	Maze III	Maze IV
1	46	19	13	5
2	36	13	6	8
3	41	17	12	8
4	26	9	8	3
5	19	9	5	3
6	29	9	11	5
7	46	6	9	8
8	25	10	15	3
9	24	7	3	5
10	29	25	4	8
11	56	42	16	15
12	28	11	12	7
13	21	10	23	5
14	33	18	9	6
15	75	14	12	7
Mean	35.6	14.6	10.5	6.4
Median	29	11	9	6
Range	19–75	6–42	3–23	3–15

The largest drop (59 percent) between any two successive learning positions appears with the first (90°) shift. It is to be noted that, in every case, the total number of trials required for learning maze II falls below that for maze I. The largest drop here was from 46 to 6 trials or 87 percent and the smallest was from 29 to 25 trials or 13 percent. It may be noted that five subjects required more trials to learn maze III than maze II. As a matter of fact, learning the same maze a third time, as under these specific conditions, may involve an *increase* in the number of trials of as much as 50 percent [an average of 9.2 trials (maze II) for these five cases as against 14 trials (maze III)]. Despite these individual increases, however, there is a total decline in mean values between patterns II and III of 4.1 trials or 28 percent. Three subjects also took more trials to learn maze IV than maze III [average 4.3 (maze III) as against 7 (maze IV)]. That is, the fourth learning of a single maze may be accompanied by an *increase* of 63 percent in difficulty over the third learning. On the whole, individuals do much better on the fourth learning. Here, as between II and III, there is a total drop of 4.1 trials from the preceding mean (III)—a decline of 40 percent. In general, the data concerning the number of trials required to learn a single maze pattern four different times, where there is definite knowledge of the identity of the pattern, clearly reveal a large decrease in degree of difficulty in connection with the first shift and relatively smaller decreases with successive shifts. The performance of the 15 subjects upon these four tasks is presented graphically in Fig. 1. This diagram shows the relative difficulty of each pattern when considered in terms of the median trials required for its learning.

In Table II, we have arranged the data for 15 subjects upon the four learning tasks in terms of the total number of times each individual entered all ten blind alleys. These data show, even more clearly than do those on the number of trials, the increased ease with which mazes II, III, and IV are learned as compared with maze I. Maze II drops 76 percent, III declines 89 percent, and IV decreases 93 percent

from the mean of maze I. In addition to the 76 percent drop between I and II, we may note a drop in mean between II and III of 54 percent while that between III and IV declines 40 percent. These decreases are to be compared for purposes of understanding with respective decreases (number of trials)

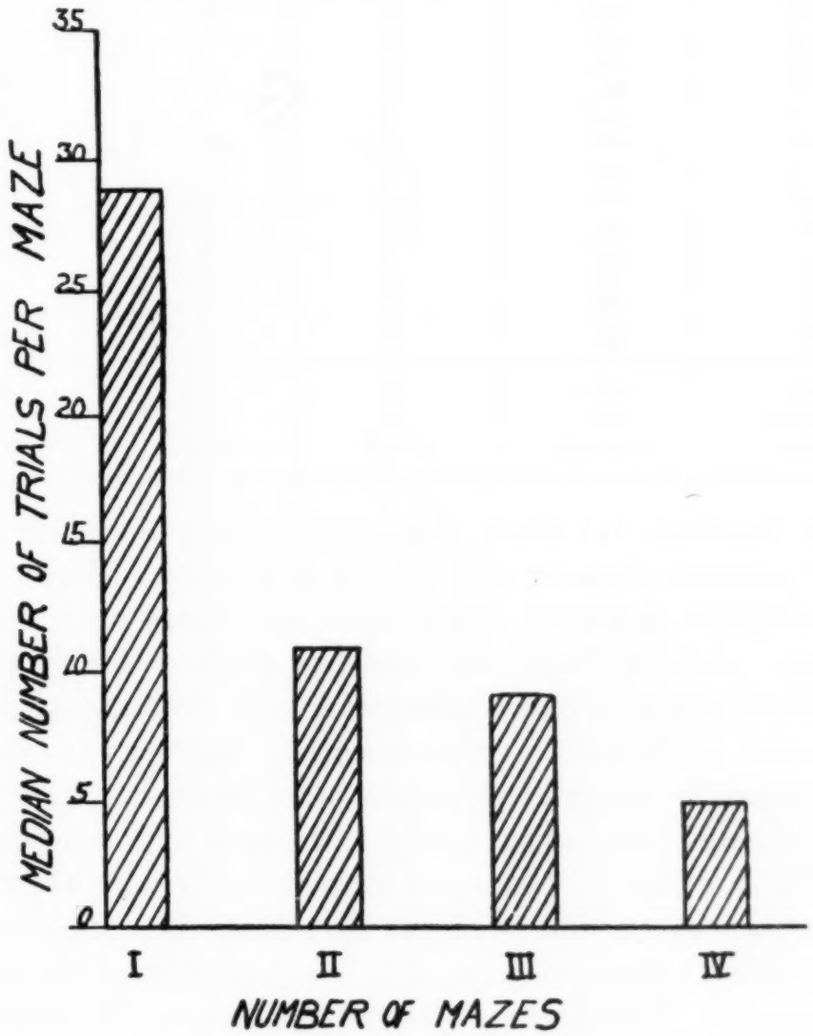

FIG. 1. Median number of trials for all subjects on all four mazes.

of 59 percent (patterns I and II), 28 percent (II and III) and 40 percent (III and IV). In view of the evident variability here, the median values give a somewhat more representative picture. We accordingly find that the declines from maze I, as based on the number of alley entrances (Table II), are 82 percent (maze II), 91 percent (maze III), and 96 percent (maze IV) respectively. The data here show that one

TABLE II

TOTAL NUMBER OF BLIND-ALLEY ENTRANCES MADE BY EACH SUBJECT ON EACH MAZE PATTERN

Subject	Maze I	Maze II	Maze III	Maze IV
1	405	51	41	2
2	237	38	15	20
3	234	62	49	15
4	136	18	10	0
5	102	11	3	0
6	169	30	17	6
7	304	5	8	8
8	118	12	26	0
9	132	6	0	2
10	172	148	3	13
11	241	256	60	81
12	107	6	11	33
13	118	25	50	4
14	166	23	5	4
15	495	59	48	20
Mean	208.4	50	23.1	13.8
Median	169	30	15	6
Range	102–495	5–256	0–60	0–81

subject (number 11) made more entrances while learning the second pattern than he did on the first maze. Each of the other subjects, however, made fewer entrances on the second learning. Among these, the smallest decline (I and II) was 14 percent which is to be compared with the largest drop of 98 percent. The latter value definitely implies that learning was practically completed on the first pattern. Contrasted with the single case of increased entrances that accompanies the shift to maze II, there are four subjects who show more alley entrances on maze III than on maze II. Thirty-three percent of all subjects (maze III) reach or exceed the median of maze II. Thirty-three percent of maze IV cases also reach or exceed the median number of alley entrances on maze III. Despite these particular upward variations, the general tendency runs in an opposite direction. In substantiation of this statement, we point out that some subjects ran maze IV perfectly on the first three trials; these cases clearly represent a fully established generalized pattern.

The data of Table II are shown graphically in Fig. 2. It is evident that the greatest decrease between any two consecutive patterns, as represented by median values, accom-

panies the first shift. The greatest amount of learning accordingly concerns maze I. Here, generally speaking, the individual develops a method of attack and, at the same time, acquires an understanding of the nature of a maze pattern, the

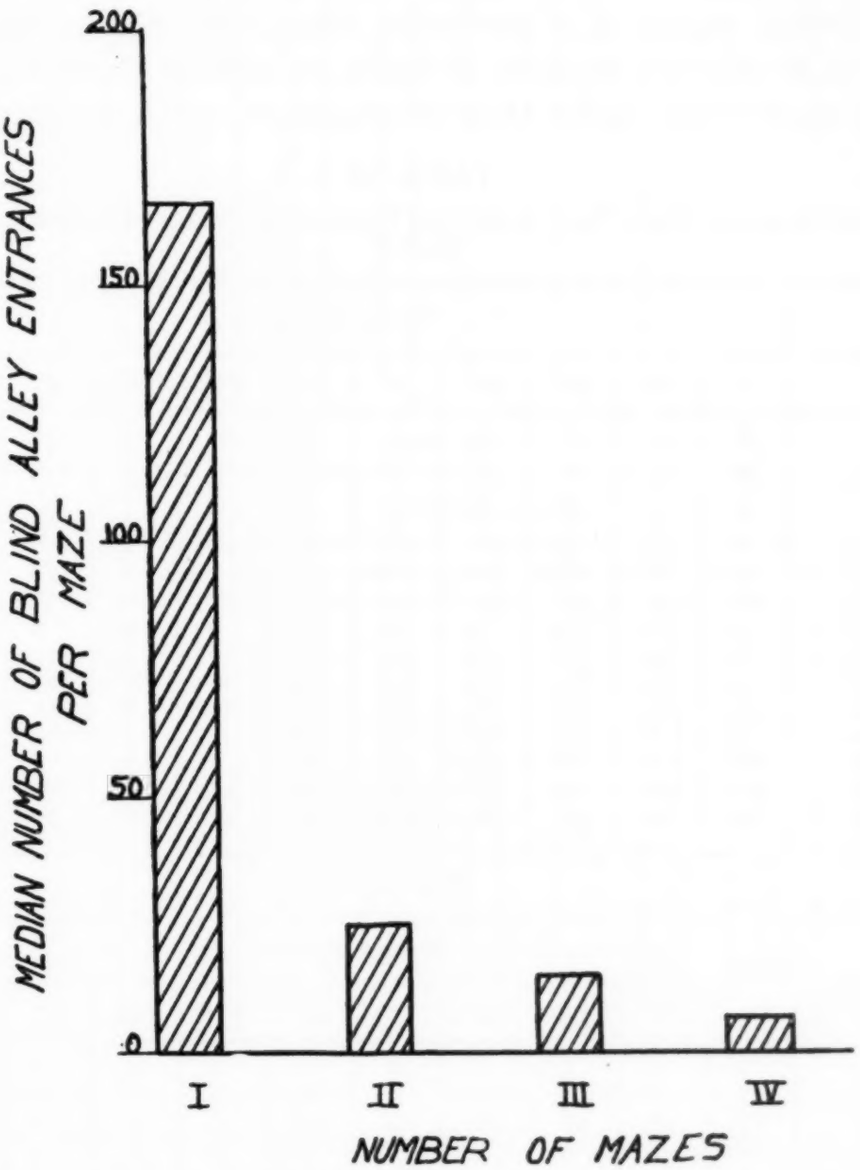

FIG. 2. Median number of alley entrances for all subjects on all four mazes.

relative positions of the start and the goal, the approximate locality of some alleys, and the specific locality of other alleys. He establishes, while learning pattern I, a perceptual-actional pattern which has both general and specific features. It is generalized to the degree that the individual is actually

able to 'fit it' to the same maze pattern, when such differs slightly in spatial relations, sufficiently as to avoid further entrance into some or all alleys. It is specific in so far as he is unable without some additional learning to avoid entering alleys. That is to say that, while he may know the approximate region of a particular alley, the subject may be forced to explore in order to learn its specific location. He may accordingly make alley entrances on the later patterns,

TABLE III

TOTAL NUMBER OF TIMES EACH ALLEY WAS ENTERED BY EACH OF FIFTEEN SUBJECTS

Maze I

Subject	Number of Alley									
	I	II	III	IV	V	VI	VII	VIII	IX	X
1	58	57	47	61	43	38	20	27	49	39
2	34	32	33	40	34	25	15	4	6	9
3	53	37	34	22	4	15	7	17	16	22
4	8	25	20	18	14	19	7	1	10	15
5	8	5	8	13	16	14	20	1	8	9
6	35	18	26	32	10	13	4	8	16	5
7	47	43	44	30	41	38	20	10	39	13
8	17	12	11	10	17	19	5	4	9	14
9	21	15	18	16	10	8	3	5	25	12
10	14	13	29	21	13	15	13	10	25	12
11	14	19	24	20	39	28	19	9	51	23
12	5	6	17	17	13	16	7	4	16	6
13	12	2	18	28	20	19	9	2	5	2
14	25	20	23	23	15	19	12	9	15	2
15	74	56	33	78	60	45	47	18	29	62

Maze II

Subject	Number of Alley									
	I	II	III	IV	V	VI	VII	VIII	IX	X
1	0	0	5	7	8	6	3	9	7	6
2	11	6	7	6	0	2	0	2	1	3
3	73	46	37	40	12	12	4	5	2	9
4	0	1	3	2	0	3	1	1	2	5
5	0	0	0	1	3	1	5	0	0	0
6	2	0	0	6	5	7	9	5	4	4
7	0	0	0	0	0	0	0	0	4	1
8	0	0	2	1	2	0	0	3	0	4
9	0	0	0	1	1	0	4	0	0	0
10	22	23	26	17	10	10	3	12	9	7
11	24	24	24	39	39	20	19	24	45	6
12	0	1	2	1	0	0	0	0	0	2
13	4	2	3	5	2	1	1	3	2	2
14	0	2	6	11	2	2	0	2	1	1
15	3	8	9	13	7	6	6	2	8	4

Maze III

Subject	Number of Alley									
	I	II	III	IV	V	VI	VII	VIII	IX	X
1	5	0	1	1	4	5	1	11	9	4
2	1	4	0	4	1	3	1	0	0	1
3	6	6	8	9	6	9	1	0	1	3
4	0	0	1	1	2	0	0	0	2	4
5	1	1	0	0	0	0	1	0	0	0
6	0	0	1	4	2	0	1	1	2	6
7	1	0	0	0	0	0	0	0	5	2
8	2	2	3	4	0	2	4	0	6	2
9	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	2	0	0	1	0
11	2	0	10	8	3	6	0	2	10	20
12	1	6	0	3	0	0	0	0	1	0
13	6	2	3	10	1	10	7	3	4	4
14	1	0	2	1	5	1	0	0	0	0
15	7	7	1	6	7	8	0	1	2	9

Maze IV

Subject	Number of Alley									
	I	II	III	IV	V	VI	VII	VIII	IX	X
1	4	0	0	0	0	0	2	0	0	0
2	3	3	4	1	1	1	1	0	4	2
3	2	1	3	2	0	2	0	0	2	2
4	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0
6	1	0	1	0	0	0	1	1	1	1
7	1	0	0	1	0	0	1	0	4	1
8	0	0	0	0	0	0	0	0	0	0
9	0	0	0	2	0	0	0	0	0	0
10	2	0	1	0	2	5	0	1	1	1
11	8	3	10	22	9	1	5	0	3	17
12	0	1	5	13	6	2	2	2	2	0
13	0	0	0	0	0	0	0	0	0	0
14	0	0	3	0	0	0	0	1	0	2
15	5	3	1	2	3	2	0	1	2	2

but not to the same extent as on the earlier ones. Generalization, as a form of learning, clearly extends beyond the first pattern. This is revealed in part by the significant *decrease* in total entrances between mazes II and III (54 percent) and III and IV (40 percent), by the *increase* in the total number of alleys *not entered* on patterns II, III, and IV and by the total number of cases where the first trials following a rotation do not show any alley entrances. Twenty percent of all subjects run pattern IV without any alley entrances. These cases reveal the pattern to be independent of the specific spatial

relations which obtain at each of the four experimental positions between the learner and the learning material. It may be noted, on the other hand, that 80 percent of the individuals have some learning to do when they reach the fourth position of the maze.

A brief examination of Table III will show the nature of the performance of the 15 subjects on the four maze patterns in terms (1) of the actual frequency of all alley entrances, (2) of particular alleys not entered, and (3) of particular alleys entered more often than on the immediately preceding pattern. The mean and median values for Table III are placed together for comparative purposes in Tables IV and V. One fact is readily derivable from these tables. Without exception, each of the ten blind alleys, when regarded in terms of the average number of times entered (Table IV), shows a

TABLE IV
MEAN NUMBER OF TIMES EACH BLIND ALLEY WAS ENTERED

Maze	First Half					Second Half				
	1	2	3	4	5	6	7	8	9	10
I	28.2	24	25.6	28.6	23.2	22	13.9	8.6	21.2	16.3
II	9.3	7.5	8.2	10	6.1	4.6	3.6	4.5	5.6	3.6
III	2.2	1.8	2	3.4	2.1	3.1	1.1	1	2.8	3.5
IV	1.6	.7	1.8	2.8	1.4	.9	.8	.4	1.2	1.8

TABLE V
MEDIAN NUMBER OF TIMES EACH BLIND ALLEY WAS ENTERED

Maze	First Half					Second Half				
	1	2	3	4	5	6	7	8	9	10
I	21	19	24	22	16	19	12	8	16	12
II	0	1	6	6	2	2	3	2	2	3
III	1	0	1	3	1	2	0	0	1	2
IV	1	0	1	0	0	0	0	0	1	1

drop on each of the three patterns following maze I. In this sense, the series of four patterns clearly reveals the effects of progressive mastery. Another fact also stands out here. When the averages of the mean entrance values for the

alleys nearer the start on all four patterns are set against like averages for the alleys nearer the goal, it is evident that the first 'one-half' of each maze is relatively more difficult. It accordingly shows relatively larger declines through the series than does the second 'one-half.' The average entrance values for alleys 1 to 5 may be grouped as follows: maze I, 25.9; maze II, 8.2; maze III, 2.2; and maze IV, 1.7. For alleys 6 to 10 (second one-half), the following values hold: maze I, 16.4; maze II, 4.4; maze III, 2.3; and maze IV, 1.

Figure 3, which is based upon the data of Tables IV and V, shows the striking degree of similarity that characterizes these four learning tasks when the comparison is drawn in terms of average number of times each alley was entered. It is to be noted here, that with four exceptions (out of a possible forty), the four curves rise and fall together. The four curves drop from alley 1 to alley 2 then rise through alleys 3 and 4 to drop again through alleys 5, 6 (one exception), 7, and 8 (one exception). All again rise on alley 9 to drop finally on alley 10 (two exceptions). Of the four exceptions, it should be noted that only one is as great as 1 entrance. The others are fractional (.9, .7, and .6). Regarded from a causal standpoint it is significant, we suggest, that 15 individuals who learn four tasks under these conditions should give such similar results. The gross behavior patterns involving the arm of the subject differed quite decidedly on the four tasks. For example, in maze I the individual in leaving the starting position moved his arm directly to his left; in maze II, he moved it away from himself; in maze III, he moved it to his right; and in pattern IV, he moved it directly toward himself. The arm, too, was differently extended on the four tasks. In maze I, for example, the start was quite near the individual; in maze III, however, he had to extend his arm over the maze so as to reach the starting position. Yet under these somewhat dissimilar spatial relations (with respect to subject), certain alleys definitely tended to be entered, on an average, more often than did others and at the same time other alleys were consistently missed. It would appear, therefore, that the basic determining conditions of alley

entrances in this study lie within the actual maze pattern itself. The differential factor here must concern those specific relational properties which exist among the alleys (including start and goal) and the several pathways which connect them. Regarded in this sense, they are fairly independent of the particular spatial relations to individual learner as well as his kinæsthetic patterns (direction of movement with respect to

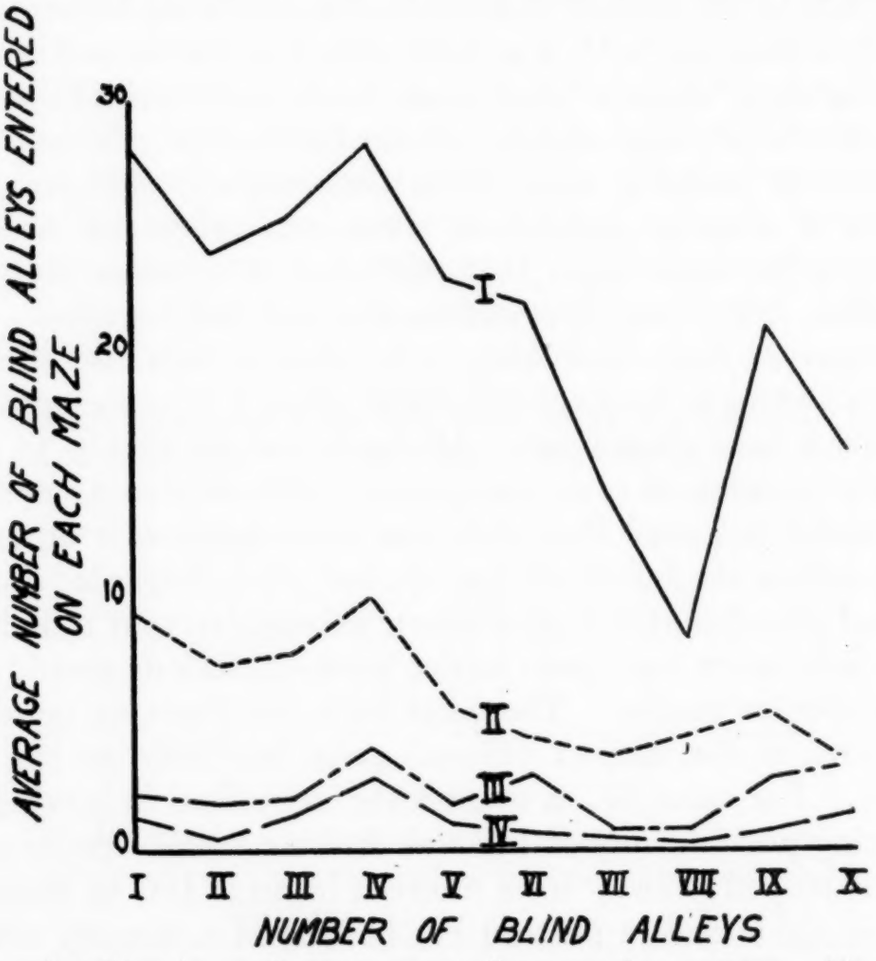

FIG. 3. A striking degree of constancy prevails among the 4 patterns. Alleys rise and fall together.

his body). We shall shortly report upon these basic relational conditions. Figure 3 also helps to an understanding of the comparative difficulty of the four patterns. The large drop between graphs I and II and the relatively smaller drops found among the other curves clearly suggest that the most striking changes occur in maze I. It must be noted, however, that this learning is of such a nature that it in no way disturbs

the uniformity with which the alleys are either entered or missed on the later mazes.

Table VI shows the average number of times that each alley was entered by 15 subjects on all four mazes (a total of 60 learned patterns). These data reveal a decided difference between the two 'halves' of the pattern in degree of difficulty

TABLE VI

A. AVERAGE NUMBER OF TIMES EACH ALLEY WAS ENTERED BY 15 SUBJECTS IN 60 PATTERNS. *B.* TOTAL NUMBER OF TIMES EACH ALLEY WAS ELIMINATED (1) FIRST AND (2) LAST IN 60 PATTERNS

Alleys	1	2	3	4	5	6	7	8	9	10
A	10.2	8.5	9.5	11.2	8.2	7.8	4.8	3.7	7.8	6.4
B 1	10	7	5	7	6	5	10	14	9	9
B 2	10	15	15	15	8	12	8	5	8	14

as measured by frequency of entrance. There are five alleys which show a mean frequency of more than 8 entrances. It is to be noted that these are the *first* five alleys. This table shows furthermore the total number of times that each alley was eliminated (1) first in 60 learned patterns and (2) last in a like number of patterns. These data are presented graphically in Fig. 4. To show relative difficulty most clearly, the ten alleys of the pattern are arranged here in their order of decreasing frequency of entrances. 'First' and 'last' eliminations for each alley are plotted upon this frequency graph.

Graph *A* shows that without a single exception the first one-half of the maze pattern is relatively more difficult to learn. The difference between the end-values of this frequency graph is 7.5. It is possibly significant that the two alleys represented by these ends, *namely*, 4 and 8, also show respectively the greatest (15) and the least (5) number of 'last' eliminations. That this ratio is not purely an expression of total entrance values is indicated by the data upon certain other alleys. Alley 1, for example, ranks next to alley 4 in terms of the actual frequency with which it was entered, yet it stands well below alleys 2, 3, 6, and 10 in the total number of 'last' eliminations. Again, alley 10 is

relatively low in its frequency of entrance but it ranks next to the highest alley in number of 'last' eliminations. We suggest, therefore, that the factor of placeness or location of alleys within the total pattern serves as a major determining factor in these variations in frequency of entrance as well as first and last eliminations. The data of Table VI also show

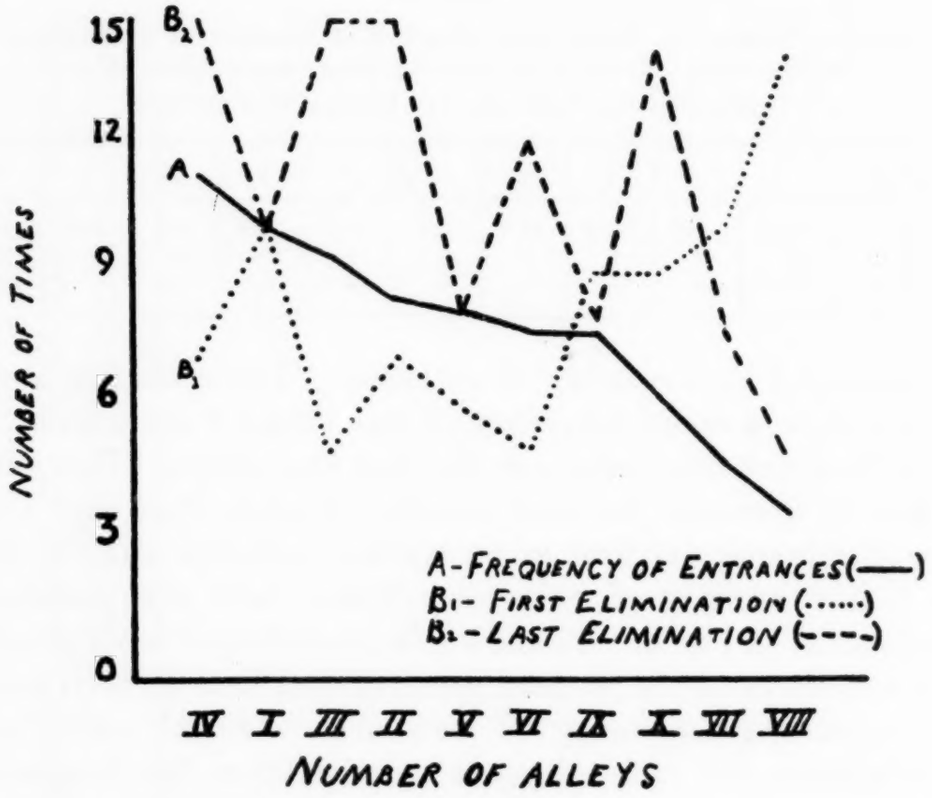

FIG. 4. Frequency of alley entrance plotted against first and last eliminations.

that the alleys of the 'first one-half' are entered more frequently (56 percent) than those of the 'second one-half.' The averages here are 9.5 entrances for alleys 1 to 5 and 6.1 for alleys 6 to 10. Moreover, alleys 1 to 5 have an average of 7 'first' eliminations and 12.6 'last' eliminations as against 9.4 'first' and 9.4 'last' eliminations for alleys 6 to 10. Generally speaking, then, alleys 6 to 10 are entered less frequently but they are really identical in number of 'first' and 'last' elimination. Alleys 1 to 5 are entered more often and they also show a significant difference in terms of the

number of 'first' and 'last' eliminations. We have as yet to determine the nature of those particular factors which produce fewer alley entrances in the 'second one-half' without producing any significant difference in terms of frequency of their elimination.

The data in Table VII assist us in understanding more clearly the character of those effects which the learning of a single maze four different times under slight changes in the spatial relations has upon entrance and avoidance of blind alleys. We represent here the total number of different

TABLE VII

ALLEYS ENTERED (ONE OF MORE TIMES) BY EACH STUDENT ON EACH MAZE—POSSIBLE 10

Subject	Maze I	Maze II	Maze III	Maze IV
1	10	8	9	1
2	10	8	7	9
3	10	10	9	7
4	10	8	5	0
5	10	4	3	0
6	10	7	7	6
7	10	2	3	3
8	10	5	8	0
9	10	3	0	1
10	10	10	2	7
11	10	10	8	9
12	10	4	4	8
13	10	10	8	2
14	10	7	4	3
15	10	9	9	9
Mean	10	7	5.7	4.3
Median	10	8	5	3

alleys in a possible 10, which were entered one or more times by each subject while learning each maze pattern. An individual score of 7 here implies that 3 alleys in a particular maze were always avoided by that subject. It is clear that the number of alleys which are not entered increases at a constant rate throughout the four patterns. In terms of the median, 20 percent of the alleys are missed on maze II, 50 percent on patterns III and 70 percent on IV.

Learning, as under these specific conditions, shows several features. Among others, it materially lessens the amount of gross or random exploration, it decreases the number of

times any particular blind alley must be entered in order to eliminate it and, finally, it reduces the total number of different alleys that are entered. The learner, on the later patterns, is not forced through recourse to sheer exploration to discover the specific location of every alley. The behavior of the subjects while learning the first maze is accordingly different from that found on the last maze. On maze IV, for instance, 7 of the 10 alleys are not entered. The individual moves safely past them. The difficulty of the learning task is accordingly reduced. Moreover, whenever a particular alley is entered, it tends to be eliminated more quickly on maze IV than on maze I. Our results clearly show that learning proceeds more or less rapidly (depending in part upon the method of attack) toward the establishment of a generalized pattern. In view of the identity of the learning tasks, the most interesting single feature as shown by Table VII concerns the relatively large number of individuals who come to the fourth learning of the same maze with a pattern of such a nature that further exploration and discovery are necessary in order for them to establish a fourth pattern. Eighty percent of the subjects need more learning. The amount is indicated by the mean difference of 1.4 between patterns III and IV.

In Table VIII, we have shown the average number of times that the alleys of each maze were entered during the first 25 (or less) trials. The difference between the first and

TABLE VIII

AVERAGE NUMBER OF TIMES THE ALLEYS OF EACH MAZE WERE ENTERED PER TRIAL

Maze	1	2	3	4	5	6	7	8	9	10	11	12	13
I	26.6	14.6	12.1	11.1	8.4	8.9	10.6	7.3	6.4	6.1	4.1	2.7	5.1
II	6.7	6.3	3.4	2.4	5	4.3	3.1	2.2	3.5	2.2	1.9	2.3	2.2
III	3.4	2.9	3.1	2.9	2.5	1.5	1.4	1.3	.3	.4	.4	.2	
IV	3	4.5	1.8	.9	.4	.7	.1						

Con't

Maze	14	15	16	17	18	19	20	21	22	23	24	25
I	3.7	5.1	5.7	4.8	4.8	5.7	3.6	4.4	4	2.5	3.4	2.1
II	1.1	2.7	1.1	.9	.3	.9	.1	.1	.5	.7	.2	.5
III												
IV												

last patterns is more apparent here. On trial four, for instance, I shows 13 times more alley entrances than does IV. The data of this table are shown graphically in Fig. 5. We have stopped the curves when the values became fractional instead of extending them so as to include the data for every

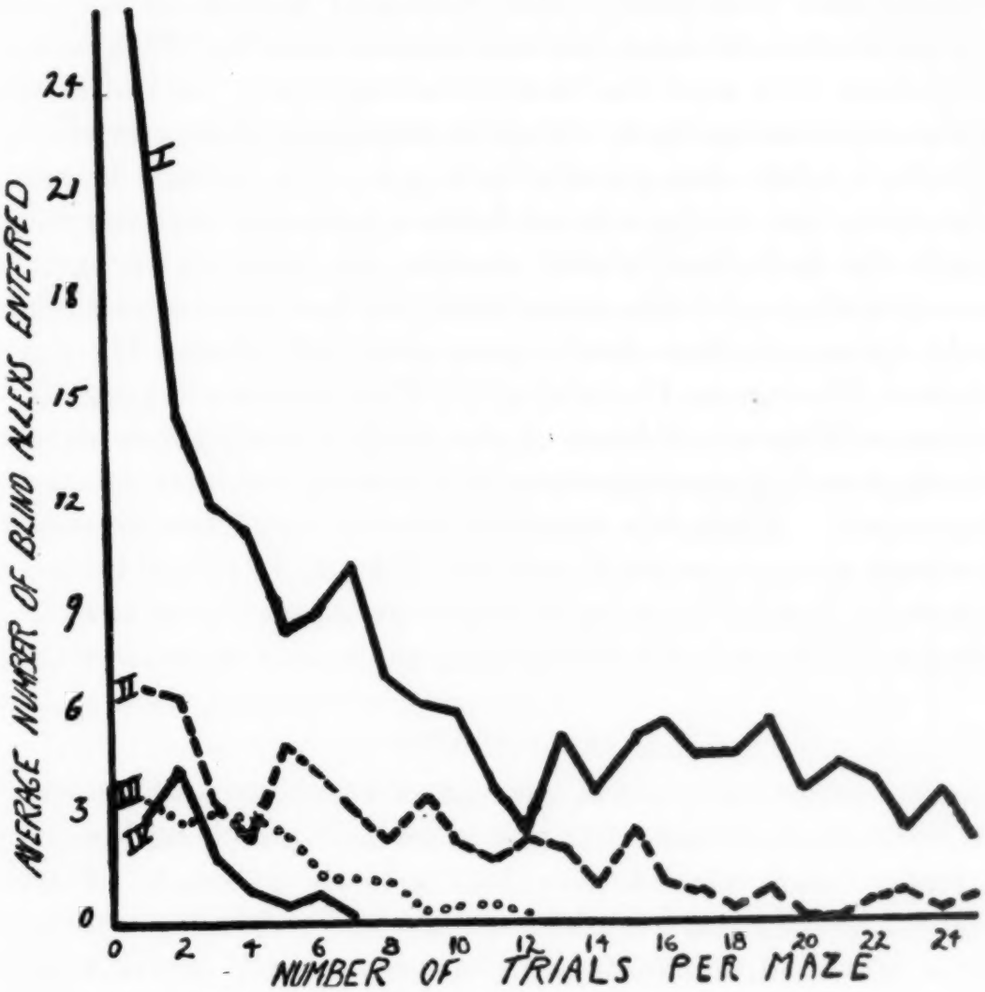

FIG. 5. Learning curves for four maze patterns.

subject (one or two cases). We have already seen that the mean trials for these four patterns are 35.6, 14.6, 10.5, and 6.4. The curves here clearly show that the largest single difference among them is to be referred to the first 11 trials on maze I. As a matter of fact, curve I drops on the 12th trial so that it almost touches the one for maze II. Curve I shows, more clearly than do the others, those features which are more characteristic of the ordinary learning curve. That

is, a fairly large initial drop occurs during the first few trials to be followed by a gradual decline. But the curves for mazes II, III, and IV lack such large initial declines. It should be noted that the curve for maze II fails at all points to touch that for maze I although they are very similar beyond the 12th trial. This relational feature of the two curves implies, we infer, that the type of learning which occurs in pattern II is more like that to be found in maze I after the gross exploratory type, which is seemingly characteristic of the first trials, has greatly declined. The attack is more directive, that is, there is much less wandering over the maze until the individual either reaches the goal or recognizes some locality. In this connection, we find that on two trials only do any of these four curves meet (IV crosses III (trial 2) and III crosses II (trial 4)). This fact, we suggest, furnishes additional evidence of the fairly unambiguous nature of the learning performances of these 15 subjects on these four tasks. While it is true that there is much less difference between the curves for II and III (III and IV) than between those for I and II, yet each begins at a lower level than did the preceding and each consistently maintains its relative rate.

Conclusion

One maze pattern was rotated as a unit around a central point in such a way that the start and goal positions, for instance, were moved over four arcs of 90° each. Under these experimental conditions, 15 male subjects, who had been informed concerning the nature of this rotation of a single pattern, learned a common unit of material four different times. No change whatsoever was made either in the physical sequence of the blind alleys or in their relative positions with respect to each other and to the start and goal positions. It must be assumed, therefore, that there was 100 percent identity or similarity among all four learning tasks as far as the maze patterns themselves were concerned. The sole difference between any two tasks concerned those particular changes induced in the spatial relations between the learner and the learning materials by rotating the

whole pattern so that the starting position, for example, was moved over a distance of 3 inches. The subject's learning problem concerned the establishment by means of a particular mode of attack of a generalized pattern which could be fitted, under these experimental conditions, to each learning situation (irrespective of specific spatial relations) in such a way as to enable him to move through the maze without entering alleys.

When achievement is considered in terms of number of trials required for learning, the four patterns (0°, 90°, 180°, 270°) give the following values: mean—35.6, 14.6, 10.5, and 6.4; median—29, 11, 9, and 6. The difference of 21 trials between the means of I and II represents a decline of about 60 percent, while the difference of 29.2 trials between first and fourth learning represents a decline of 82 percent. The largest single drop between two consecutive tasks occurs between patterns I and II. Considerable variability appears as a resultant of a particular mode of attack. For some individuals, the third period of learning may possibly involve an increase in number of trials as great as 50 percent over that of the second learning, and the fourth learning may show a 63 percent increase over the third.

A comparison of the values for the number of times each alley was entered (number of errors) reveals more clearly than do the data for trials the actual rate at which the establishment of a generalized pattern proceeds on the successive learning occasions. The entrance values for the four patterns are as follows: mean—208.4, 50, 23.1, and 13.8; median—169, 30, 15, and 6. Mazes II, III, and IV thus drop 76 percent, 89 percent, and 93 percent respectively from the mean of maze I; they drop 82 percent, 91 percent, and 96 percent from the median of maze I. The rate (extent) of this establishment (generalized pattern) is also indicated in part by the fact that 20 percent of the subjects on maze IV met the criterion for mastery on the first three trials; that is, no entrances were made. Thus 80 percent of the subjects still have some learning to do on a single pattern which they had learned three times previously on the same day. Some subjects

actually made more entrances on IV than on III. The data clearly reveal that certain alleys tend to be entered more and that other alleys tend to be missed more often than others on all four learning tasks. The consistency is such that with four exceptions, all alleys rise and fall together. The establishment of a generalized pattern proceeds so consistently that, the curves for alley entrances (four patterns) do not touch at any point (Fig. 3).

The basic determination of alley entrance or avoidance is assumed to be inherent in the total pattern itself. It is unquestionably independent of the behavior (kinæsthetic) pattern of the individual as determined by the spatial relations sustained between the maze and the learner. Each (behavior) pattern differed from the others. To leave the starting position of maze I, for instance, the subject moved his arm directly to his left; to leave II, he moved away from himself; to leave III, he moved directly to his right; and, to leave IV, he moved directly toward himself. Despite unlike spatial relations, each alley on each pattern shows a high degree of constancy in terms of influence upon entrance. The differential factor lies within the maze pattern. We suggest, therefore, that the various alleys in a maze are not entered in accordance with sheer chance. The method which we employ here reveals that there are factors, independent of the individual learner, which work constantly to determine entrance or avoidance.

The two 'halves' of the maze show a significant difference in terms of frequency of alley entrances. The average entrances of the first 'one-half' in maze I, for example, were 56 percent greater than on the second 'one-half.'

We are also able to show that frequency of alley entrances seemingly has little bearing upon 'firstness' and 'lastness' of elimination. Two widely separated alleys may be entered, on the average, a like number of times. The one, however, may show three times more 'last' than 'first' eliminations, while the other may show the same number of first and last eliminations or it may be eliminated first more often than last. The first five alleys show 80 percent more 'last' than 'first' eliminations. Alleys 1 to 5 show fewer 'first' and more 'last' eliminations than do alleys 6 to 10.

Learning under these conditions has a significant effect upon the total number of different alleys entered during the four periods. There is a striking increase from pattern to pattern in the number of alleys which are not entered; namely, 0 (I), 2 (II), 5 (III), and 7 (IV). There is, therefore, much less exploration on the later mazes. The individuals tend to shift the learned pattern in part to accompany the rotation; the applicability being dependent upon the method of learning. While exploration occurs on the later patterns, the alleys are more quickly eliminated. Learning curves based upon number of alley entrances made per trial for each maze show a high degree of consistency. On two trials only do any two of the four curves touch. With the exception of the first ten trials on maze I, in which the exploratory type of learning is clearly dominant, the four curves reveal a common mode of learning. It is this form of learning which can be best studied under these particular experimental conditions.

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EXPERIMENTAL EXTINCTION OF VERBAL MATERIAL

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Introduction

Discussions of the general applicability of the conditioned response often include the statement that the phenomenon of experimental extinction, which has been repeatedly demonstrated to appear in the 'typical' conditioned reflex situation, is not characteristic of the more common forms of learning, and from this fact it is deduced that conditioning principles are therefore not basic for learning. Thorndike points out, for example, that the conditioned response shows extinction with repetition while, "ordinary learned connections do not act in this way" (**14**, p. 110). Such statements as this are open to question on two scores. In the first place, there is accumulating evidence that the conditioned response itself is not always subject to extinction (**11**) and in the second, very few systematic attempts have been made to discover the existence of extinctive processes in the more usual learning situations.

Dunlap (**1**, p. 78) in his *beta* hypothesis has stated that the "occurrence of a response lessens the probability that on the recurrence of the stimulus pattern the same response will recur," and has offered some experimental evidence in support of this hypothesis in studies of complex motor acts such as typing and stuttering. If these results can be verified (**6**), they may possibly be shown to share fundamental features with the phenomenon known as experimental extinction, whatever that may be. If, however, the attempt is to be made to apply conditioning principles generally to all learning

[1] The results of this experiment were reported at the American Psychological Association at Ann Arbor, 1935 (**10**). The senior author planned the experiment and interpreted the results. The junior author conducted the experiment and assisted in the preparation of statistical material.

situations,[2] it is necessary to determine experimentally how far each of these principles is actually operating in each of the situations to be included in the generalization. The deductive method cannot circumvent this necessity.

It has been suggested that the nature of the material learned may be one factor setting the limits of generalization for certain phenomena of conditioning. For example, Hudgins' well known experiment (**4**) has seemed to indicate that the conditioned pupillary response to verbal stimuli shows no extinction whereas the same response to other stimuli may undergo decrement under similar conditions. The fact that a repetition of this experiment (**13**) has not produced the same results need not concern us here, for regardless of the issue of this controversy the further question remains whether extinction is obtainable when the response, as well as the stimulus, is verbal. Interest in this question, which suggests an additional situation in which conditioned reflex principles should be tested, has led to the formulation of the present exploratory experiment.

As a first step, we have endeavored to devise a situation descriptively similar (save in the use of verbal material) to those experiments in which extinction has often appeared. Examination of statements of the conditions and characteristics of experimental extinction shows them to be far from definite and complete. Apparently, however, the most essential descriptive characteristic may be stated as decrement of a conditioned response under a loosely defined set of conditions which always includes repetition of the conditioned (secondary) stimulus *without* the unconditioned (primary) stimulus.[3] Many other conditions have been described which modify the course and amount of the decrement, but none of these descriptions tells us anything positive about the essential determinants of the phenomenon. Theories of their nature

[2] See Hull (**5**), and other papers in which conditioning principles are utilized for the deduction of the phenomena of maze learning, verbal serial learning, etc.

[3] 'Primary' is the preferable term here, for it need not imply anything about the learned or unlearned nature of the attachment between the primary stimulus and its response. This is important, for obviously it is possible to extinguish a secondarily conditioned response; *i.e.*, one already conditioned to a stimulus before the present conditioning occurs.

provide basic problems a-plenty but no answers. It is clear that as long as you cannot control the basic antecedents of different kinds of responses whose changes are being compared, your experiment can do no more than reveal the similarity or difference in the course of this change under the apparently similar conditions. So the present experiment can attempt to answer only the question whether verbal responses do or do not show decrement (extinction) comparable to that shown in non-verbal response under apparently similar conditions; *i.e.*, conditions in which the subject is presented repeatedly with the secondary (conditioned) stimulus without the primary (unconditioned) stimulus. Nothing can be implied about the identity of the underlying conditions of the phenomenon in the two cases, for data on this point are as yet lacking.

The Experiment

The procedure of the experiment consisted of the following steps: (1) paired repetition of 8 pairs of nonsense syllables to the point of one correct trial (*i.e.*, a trial on which all second syllables were correctly anticipated); (2) a further trial on which E secured measures of time elapsing from her pronunciation of the first syllable of a pair to S's recall of the appropriate second syllable; (3) extinction procedure for experimental syllables. At this point S's were divided into two groups for which the procedure was slightly different; (4) immediately after extinction a re-test trial of latencies for recall of all second syllables; and finally (5), a test trial of recall time for all second syllables 24 hours later.

Material.—8 pairs of nonsense syllables were chosen from Glaze's list with association values ranging from 60–87 percent. The second syllables of the pairs were printed on the disc of a Ranschburg memory apparatus which was placed in series with batteries and a key operated by E. Each time the circuit was closed, the disc turned to a new sector. Blank sectors were left between each syllable. A Cenco interval timer operated by 110 volt A.C. was in series with resistance sufficient to lower the current below that required to move the hands. When the experimenter pressed a key in parallel with this resistance the dial hands started moving promptly. When E released the key the circuit was broken and the hands stopped.

Learning the Pairs.—40 subjects, women undergraduates, were used in the experiment. A subject was seated before the apparatus and instructed as follows: "When I say 'ready,' fix your eyes on the aperture in the apparatus and listen to me. I shall pronounce a syllable. Immediately a syllable will appear before you which you are to pronounce. Then I shall pronounce another syllable which will in turn be followed by a syllable in the apparatus which you will pronounce, and so on to the end of the series." The first member of the initial syllable pair (corresponding to the conditioned stimulus) was then read aloud by the experimenter who at the same time pressed one key starting the timer and another key which exposed to view the second syllable of the

pair (corresponding to the unconditioned stimulus).[4] This syllable remained in view for one sec when E again pressed the proper key and exposed a blank sector for 5 sec, to be followed by the auditory presentation of the first syllable of the second pair, the visual presentation of the second syllable of the second pair, etc. On each trial the timer key was released by E when S pronounced the second syllable, though no record was made of latencies until after the second syllables were all learned. The first and last pairs remained the same throughout (they do not figure in the results). The positions of the middle six pairs were changed on each trial in order to eliminate serial learning.

This procedure was followed through 7 trials. Then the first syllable of the initial pair was presented and E waited 5 sec before presenting the second syllable in order to determine whether S would anticipate the second syllable. The same was done for the last pair. About half of the S's began at this point to anticipate without instructions, a situation quite comparable to the usual course of conditioning. When this happened E thereafter let 2 sec elapse between each first and second syllable and this continued until S had correctly anticipated all the syllables in a single trial. The other half of the S's showed no such tendency to anticipate. In this case, simultaneous presentation of syllables continued through 5 more trials (*i.e.*, until the end of the 13th trial), when once more an interval was introduced between syllables one and 2 of the first and last pairs. If anticipation did not occur this time S was instructed to attempt to anticipate the second syllables which for the remainder of the series followed two sec after the first. This was continued until S correctly anticipated all second syllables in a trial. Since there were no apparent relevant differences between results of S's who anticipated with and without instructions, the data are not divided on this basis.

After the correct trial all S's were given one more trial, the test trial, on which E read the initial syllables again and recorded the latency of S's responses. On this trial E waited a maximum of 30 sec for S's pronunciation of the second syllables.

Extinction procedure followed immediately. Three of the six middle pairs of syllables were selected for extinction, and the remaining three served as controls, each syllable pair being used as often in one group as in the other. Each initial member of the 3 pairs chosen for extinction was then read aloud by the experimenter 50 times alone, followed each time by a blank in the memory apparatus. About one sec elapsed between each repetition. Four times during the 50 trials the first or last syllable pairs were inserted into the series, their second syllables appearing in the aperture as during learning. This was designed to keep S's attention on the aperture and to give point to the instructions in Group II. To half the subjects (Group I) no instructions were given at the beginning of the extinction procedure; to the other 20 subjects (Group II) the original instructions, "to pronounce the syllables which appeared in the aperture" were repeated at this time. The S's in Group I always started extinction by continuing to give the second syllables, but usually ceased doing so before the end of the series, more often than not showing marked signs of perplexity at the procedure. Queries were ignored. The few who did not cease to pronounce the second syllables constitute the chief exceptions to the general trend of the results. The members of Group II uniformly ceased pronouncing the second syllables aloud after hearing the instructions.

The re-test trial followed immediately after extinction procedure was complete. S was told that E would pronounce all the first syllables of the pairs as she had done

[4] E practised thoroughly the coördinations involved in this procedure before the beginning of the experiment. 18 subjects were put through a procedure essentially like the present before the results here reported were obtained.

during learning and that S was to respond in each case with the syllable that had originally followed the pronounced syllable. E then read the initial syllables of the 8 original pairs and reaction times for the recall of the second syllables were recorded. Here as in the test before extinction, E waited 30 sec for the recall of each syllable. In all cases care was taken to equate position effects in arranging the order of presentation of control and experimental syllables on test and re-test trials. *Twenty four hours later* another test trial was given identical with those before and after extinction.

Results

1. *The Effect of Extinction Procedure on the Recall of Syllables.*—Table 1, column 1, indicates that in both Groups control and experimental syllables were satisfactorily equated in degree of learning before extinction, the critical ratio of the difference between controls and experimental syllable latencies being 0.14 in Group I and 1.49 in Group II. Since in both Groups control reaction times are slightly longer than experimentals, the small and unreliable differences are actually in the direction of a greater degree of learning for the experimentals. It is in spite of this, then, that the following results were obtained indicating a greater amount of extinction for experimental syllables. In Group I, where no instructions were given at the beginning of extinction, 23.3 percent of the second syllables in the experimental group were forgotten or incorrectly recalled on the retest trial, and 18.3 percent of the control syllables were similarly affected. In Group II, where the second syllables were not pronounced at all during extinction, the differences were much greater: 25 percent of the extinction pairs and only 6.6 percent of controls were disrupted. In other words, recall was less perfect for pairs put through the extinction procedure than for controls.

2. *Effect of Extinction Procedure on Latency of Responses.*—There are good precedents for the use of latency of response as a measure of its facility and its freedom from inhibition, both for verbal material and for motor and glandular response. Simley (**12**) and more recently Ward (**15**), following Müller and Pilzecker (**7**) and others, have demonstrated that latency grows shorter with practice even after all responses have been learned to the point of correct recall. Pavlov early described an increase in latency of the conditioned

salivary response as one mark of the onset of extinction (**8**, p. 43), and this has been demonstrated by many others.

The results stated in terms of latency show the same direction indicated by the number of syllables forgotten or incorrectly recalled. This is evident in Fig. 1 and in Table 1, columns 2, 3, and 4. The average reaction times in Table 1 include the reactions of all subjects in the stated Group with each syllable treated as a separate case. Average reaction time before extinction is shown with N = 60 in column 1 and with a different N in column 2. The latter average includes only those cases included in the average reaction time after extinction and so is more strictly comparable with this value. Averages in column 3 are based on post-extinction trials in which correct responses were made to first syllables in the stated 30 sec time limit. Comparison of the change in latency consequent to extinction (see columns 2 and 3, Table 1, and Fig. 1) for experimental and control syllables shows that in both Groups the experimental syllables decreased in speed considerably more than did the controls. Indeed, in Group II, the average speed of the controls actually increased. Furthermore, in both Groups the stand-

TABLE 1

LATENCY OF PAIRED ASSOCIATES IN SECONDS

Group I		1 Before Extinction	2 Before Extinction	3 After Extinction	4 Difference After-before
Extinction Syllables	Mean	4.98	4.43	6.91	2.47
	N	60	46	46	46
	σ	2.36	1.75	4.1	4.08
Control Syllables	Mean	5.04	4.59	5.16	0.58
	N	60	49	49	49
	σ	2.31	2.34	2.27	2.84
Group II					
Extinction Syllables	Mean	5.04	4.75	7.87	3.13
	N	60	45	45	45
	σ	2.75	2.24	5.78	5.97
Control Syllables	Mean	5.89	5.71	5.2	−0.52
	N	60	56	56	56
	σ	3.43	3.35	3.24	4.14

ard deviations of average latencies of experimental syllables increased markedly after extinction, while the variability of the controls decreased slightly.

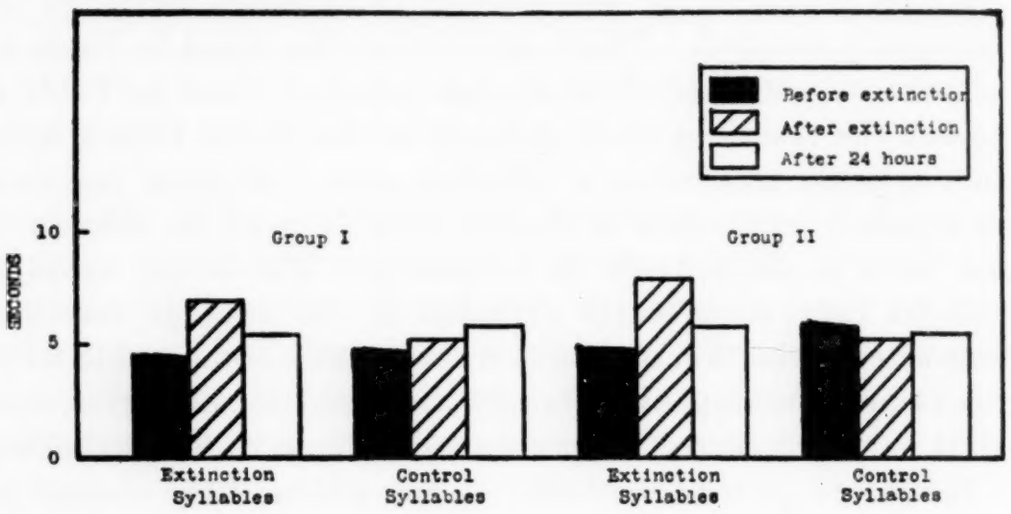

FIG. 1. Latency for recall of paired associates before and after extinction and after 24 hour interval.

The absolute size of these latencies is of course increased in amount by the experimenter's own reaction time,[5] while the variability of the measures is increased by E's variability plus the individual differences in absolute reaction times of

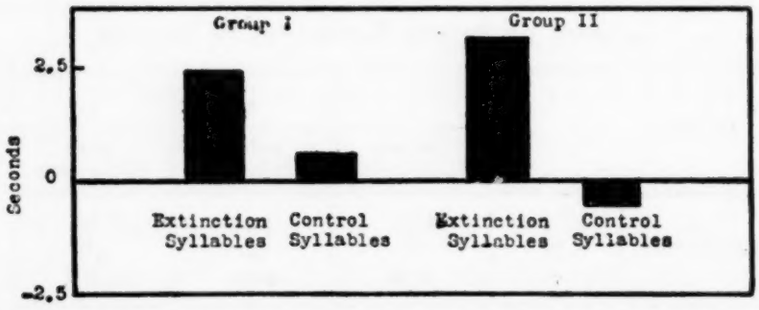

FIG. 2. Average difference in latency before and after extinction (After—before).

the subjects. The effect of the absolute size of E's reaction time on the averages may be ruled out by subtracting each pre-extinction latency from the post-extinction latency of a given syllable. The averages of these differences appear with their sigma's in column 4, Table 1, and in Fig. 2. Here it is seen

[5] E's reaction time in the present situation was taken on 2 separate occasions. On the first $M = 0.68$ sec., $\sigma = 0.44$, $N = 94$. On the second, $M = 0.657$, $\sigma = 0.33$, $N = 112$. Putting all values together, $M = 0.66$ sec., $\sigma = 0.4$, $N = 206$.

that for Group I the average latency increase after extinction for experimental syllables was 2.47 sec; for controls, 0.58 sec. In Group II, the increase for extinguished syllables was 3.13 sec, corresponding to a decrease of 0.52 sec for controls. The critical ratio of the difference between control and experimental values is 2.6 for Group I and 3.5 for Group II.

In order to compare the control and experimental latencies subject by subject, a further calculation has been made. After figuring for *each S* the average difference before and

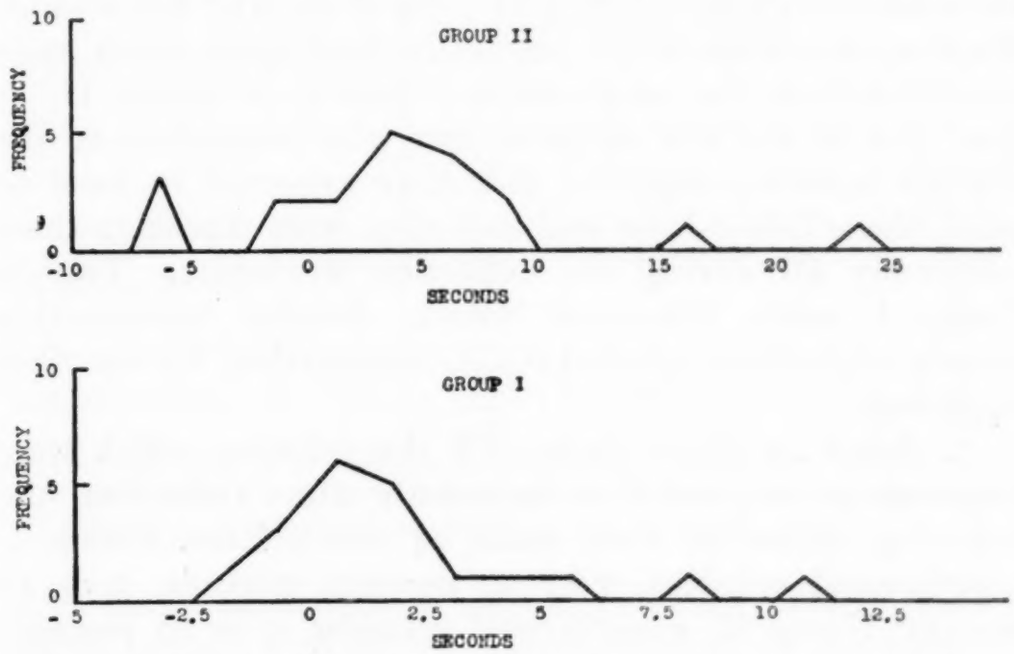

FIG. 3. Distribution of differences between change in latency of experimental and control syllables as a result of extinction procedure (Control values subtracted from experimental values).

after extinction for experimental syllables, and for controls, the latter was subtracted from the former (experimental − control). When this quantity turns out to have a plus sign, it signifies that for the given subject the experimental latencies increased more or decreased less following extinction than did the control latencies. Conversely, if the sign is minus, the control latencies increased more or decreased less than the experimentals, in which case no inhibitory effect could be imputed to the extinction procedure. Figure 3 shows the distribution of these final comparisons. In Group I the average difference between change in experimental and

change in control latencies as a consequence of the extinction procedure is 2.29 sec in favor of the experimental syllables, $\sigma = 3.26$, N = 20. In Group II the mean is 4.08 sec in the same direction, $\sigma = 7.2$, N = 20, suggesting once more that the extinction procedure as such, tended to increase the latency of the responses subjected to the procedure. The ratio of the average difference to the standard deviation of the mean is 2.53 in Group I and 3.1 in Group II. It is of interest to notice that in Group I only 4 of the 20 subjects show minus values; in Group II 5 out of 20 have minus signs. Further, the range below zero is in both cases much more restricted than the range above. Finally, in Group II, at least two of the five subjects who were exceptions to the average tendency reported that they expected to have to recall the syllables later and that they were repeating them subvocally all during the extinction procedure. Two in Group I made this same report. Careful introspective records might have revealed similar explanations for the other exceptions.

3. *Retest 24 Hours Later.*—Of the syllables which were forgotten or responded to incorrectly after extinction, the following recoveries were made 24 hours later: Group I, experimental syllables, 7 or 50 percent; controls, 5 or 45 percent; Group II, experimental syllables, 9 or 67 percent; controls, 2 or 50 percent. Approximately the same number of new syllables was forgotten after this interval in all conditions.

Table 2 and Fig. 1 present the data on latencies after 24 hours. In terms of average reaction times recovery occurred for the experimental syllables in both Groups, suggesting a parallel to the phenomenon of spontaneous recovery. These changes in the average are accompanied by a decrease in the standard deviations of experimental latencies and an increase for controls. When the latency of each syllable after extinction was subtracted from the latency of the same syllable after the 24 hour interval and these values were averaged, the items in column 2 and 4 of Table 2 were obtained, showing the average change in latency after 24 hours. A plus value

indicates that the latency has increased; a minus value, that it has decreased. A comparison of these changes for control and experimental syllables may be made in terms of the critical ratios of difference but these ratios must be interpreted in the light of certain experimental observations on the results included. For Group I the critical ratio is 1.71 and for Group II, 2.21. In Group I, 66 percent of the subjects show a greater decrease or a smaller increase in latency after

TABLE 2

LATENCY OF PAIRED ASSOCIATES IN SECONDS

		Group I		Group II	
		After 24 Hours	Difference* After-before 24 Hours	After 24 Hours	Difference* After-before 24 Hours
Extinction Syllables	Mean	5.44	−0.97	5.62	−2.51
	N	41†	34†	49	40
	σ	3.43	4.47	3.09	6.92
Control Syllables	Mean	5.7	0.62	5.42	0.16
	N	44†	39†	51	50
	σ	3.28	3.11	3.38	3.7

* See Table 1, Column 3, for values before 24 hour interval, *i.e.*, after extinction.
† Two subjects (6 syllable pairs) were not retested after 24 hours.

24 hours on experimental than on control syllables. Half of the 33 percent who did not show this trend are the same subjects whose latencies revealed no experimental extinction. In Group II, 75 percent of the subjects show the trend indicated by the average and again the five subjects (25 percent) who are exceptions are the same five who did not show evidences of being affected by the extinction procedure. In all these cases there was presumably no extinction from which to recover.

It would be suspected that rehearsal during the 24 hour interval was responsible for the improvement in performance on experimental syllables, had there not been the same opportunity to rehearse the control syllables which showed a loss rather than a gain in retention. None of the subjects had any idea of the significance or purpose of the experiment and were asked specifically not to discuss the experiment with

each other. It is unlikely that they would have rehearsed only the experimental syllables under these circumstances.

Discussion

The results give evidence that under the conditions of the present experiment and within the limits of its errors, decrement in verbal response ensues as a consequence of a procedure similar to that which has been called experimental extinction. More cases should be studied before the conclusion can be said to be established and certain apparatus refinements are desirable.[6] In view of the consistency of the findings, however, a discussion of their meaning is justified.

In the interpretation of results it is necessary to take into consideration the specific conditions of the present experiment which differ in certain respects from those typically present in the conditioning situation. In the first place, the technique used here has not made it possible to obtain a picture of the course of extinction as measured by latency changes, for sampling of the latency has been made only at the end of the extinction series. It is worth noting, however, that certain aspects of the behavior were quite typical. In Group I, for example, where no instructions were given at the beginning of extinction, pronunciation of the paired second syllable tended to drop out in a manner very characteristic of extinction in conditioning experiments, with the same tendency for syllables to recur with decreasing frequency as unpaired repetition continued.

Perhaps the most marked divergence from the usual procedure is found in the retest after extinction. This test was made under instructions to pronounce the second syllable which originally followed the first during learning, so that the subject was left in no doubt as to what was expected of her. This fact is important, for it eliminates from consideration in the present case a commonly proferred explanation of the extinction of the conditioned response. Finch and Culler (**2**), for example, have suggested that extinction is due to a failure in energy incident to withdrawal of the primary

[6] A voice key should be employed in order to reduce the variability introduced by E's reaction time. This would increase the reliability of the results.

stimulus, the incentive. In this case, if motivation of the conditioned response is made independent of the primary stimulus so that it does not disappear when this stimulus is withdrawn, extinction should not occur. Actually these experimenters succeeded in delaying markedly the onset of decrement of conditioned withdrawal responses by substituting a buzzer as a symbol of the shock and continuing to present the buzzer throughout the extinction series. They did, nevertheless, obtain extinction after a time even under these conditions, a result which suggests that the incentive is indisputably of great importance but that alongside it some sort of inhibitory process is operative. In the present experiment the subjects knew on retest trials that they were expected to reproduce the paired associates, but despite this perfectly definite motivation,[7] there was evidence of increase in latency of responses and in the number of responses forgotten after extinction. This fact must be explained on other grounds than lack of incentive.

The use of control syllables also introduces a procedure unlike that of the usual conditioned response situation but makes possible a further sifting of acceptable explanations of the observed response decrement. Guthrie (**3**) and others have proposed the notion that extinction is inhibition caused by a temporary set or posture established possibly by the emotional disturbance incident to the withdrawal of reinforcement. Were this the chief factor at work, all responses occurring under such an inhibitory set should be affected. Certainly in the present experiment the general set on the background of which experimental and control syllables were presented for retest was necessarily the same and any emotional component in this set should have inhibited all responses. In Group I we do find that the control syllables show some increase in latency after extinction though not as much as the experimental syllables (Figs. 1 and 2). In so far as this is a real effect and not accidental, it suggests that we may be dealing with a phenomenon like Pavlov's secondary extinction (**8**, 54), and a general inhibitory set might be

[7] Motivation is here used with a purely operational meaning, refering to the instructions which were given to the subjects preceding the retest trial after extinction.

responsible for such a result. It was evident to the experimenter that some of the subjects were greatly perplexed by the extinction procedure and this may well have built up a general attitude of uncertainty, with possible emotional content. Even though this should prove to be the correct explanation of the spread of extinction to control syllables, some other explanation must be sought for the greater inhibition of the experimental syllables in both Groups I and II. Indeed, in the latter Group the increase in latency following extinction is confined entirely to the experimental syllables, the controls actually decreasing in latency on retest.[8]

It remains, then, to suggest what might be the source of this inhibition which occurs even when the subject is set to make the response and which tends to be specific to the syllables put through the extinction procedure, even though these are tested in random order along with controls. On the basis of the data offered thus far in this discussion, there appears to be little to choose between the conventional Pavlovian doctrine of cortical inhibition (**9**) and the notion of inhibitory conditioning elaborated by Guthrie [9] (**3**, Ch. V). Presumably the cortical cells most directly connected with a response might undergo the greatest fatigue and consequent inhibition, as Pavlov suggests, and because of this a specific effect would be expected along with the possibility of spread of inhibition to near-lying regions. It is equally plausible to suppose that the extinction procedure has caused a new and

[8] It is impossible to be certain that some such general effect has not been obscured by whatever factor is tending to decrease the latency of the control syllables. The present experiment does not provide the data for discovering the source of this decrease in latency of the control syllables in Group II but it may be noted that the phenomenon bears a resemblance to reminiscence which Ward has observed at intervals similar to that between our test and retest series (about 3 or 3.5 minutes) (**16**). A control group of subjects should be run in order to determine the course and amount of change in syllable latency after this interval of time in the absence of extinction procedure. This might uncover evidence that in our present conditions the real extent of inhibition is partly obscured by the operation of some antagonistic effect like reminiscence.

[9] As has been stated, Guthrie tends to favor the set theory of extinction, though he also suggests that extinction may be an instance of inhibitory conditioning (**3**, p. 77). At one point (*ibid*, pp. 83–4), however, he appears to make a distinction between extinction as temporary and inhibitory conditioning as more permanent. It would seem that inhibitory conditioning, like all response, must be more or less temporary, at least in the sense of being relative to the strength of its antagonistic responses.

interfering type of response to be attached to the syllables so treated, and this again would be expected to be relatively specific in effect. This could have occurred readily in either Group. It will be remembered that when instructions "to pronounce the syllables which appeared in the apparatus" were inserted at the beginning of extinction (Group II), the subjects began immediately to give *no response* to the syllable read by the experimenter, except on the few occasions when an extra syllable pair was inserted into the series and the second syllable was presented visually (see p. 6 above). This habit of giving no response to certain syllables may well be a very positive reaction and it is certainly antagonistic to the original tendency. It is further possible in either Group that the evident response of surprise or uncertainty or bewilderment may have been the interfering reaction pattern which became directly attached to the extinguished syllable. This would explain the specificity of the inhibition more adequately than the single assumption that such emotional responses create a general disturbance in the set under which the subject is reacting, though neither assumption excludes the other. Both may be operative. As has been suggested the spread of inhibitory effect to controls in Group I calls for a general factor whereas the specific inhibition in both Groups suggests something like this conditioning of a certain stimulus to the inhibitory response. The increase in variability of experimental syllables after extinction is further suggestive of the presence of additional factors specific to these syllables and without influence on the controls.

Accumulating data [10] and a desire to avoid wholly untested postulates lend plausibility to the explanation in terms of inhibitory conditioning. In concluding, it may be pointed out that the present experiment provides one suggestive bit of evidence in favor of this interpretation. It will be remembered that the extinction procedure consisted in repeating each of three experimental syllables 50 times successively, so that the amount of inhibition (increased latency) in those syllables extinguished first, second, and third may be com-

[10] See for example, Wendt's recent article (16) in which inhibition appears as a pattern of positive reaction tendencies.

pared. On Pavlov's theory it would be expected that if any change occurred, the syllables which came earliest in the extinction series, having a longer time in which to recover before retest, should show less inhibition.[11] On the other hand, if inhibitory conditioning and general set were the factors at work, the amount of inhibition after extinction would depend, among other things, on the degree to which the interfering habit had been established and the amount of emotional interference arising during extinction. On examining Group I, it was found that the average increases in post-extinction latencies had the following values: syllables extinguished first, 2.53 sec; second, 3.14 sec; third, 1.83 sec. In Group II the values were: first, 4.25 sec; second, 3.10 sec; and third, 2.04 sec. The differences in these values are of varying degrees of reliability. In Group I 52.6 percent of the S's had longer latencies on the second than on the first syllable extinguished, a difference little better than chance. 61.1 percent of the S's showed a shorter latency for the third syllable than for the second. In Group II 58 percent of second syllables were shorter than firsts and 55 percent of thirds were shorter than the seconds.

The most reliable differences are those between the third syllables and those preceding; that is to say, the syllables closest in time to the retest tended to show least inhibition. This is opposite the expectation arising out of Pavlov's theory. In terms of the theory of inhibitory conditioning, however, this tendency might be attributed to a decrease in the amount of emotional reaction as the extinction series progressed. The S's did give evidence of less bewilderment and perplexity toward the end of the extinction procedure. This being the case, the last syllable put through this procedure (repetition 50 times alone) would actually have had less opportunity of being conditioned to the inhibitory emotional reaction.

The small and unreliable longer latency of the first syllable as compared to the second in Group I is also explicable in terms of inhibitory conditioning, should it prove on further

[11] Disinhibition might also be expected to take effect on the syllables extinguished first.

investigation to be a real tendency. In this Group, S's continued to pronounce the paired associate through a part, if not all, of the extinction trials of the first syllable extinguished, but tended to do this less and less as the series continued, whereas in Group II this explicit pronunciation of paired associates never occurred, making it possible for practice on the interfering habit (*i.e.*, either the habit of making no response or the emotional response) to begin at once.

It must be made clear that these comments are intended only as suggestive possibilities. It is evidently impossible to establish the extent of operation of any one of the many possible factors which may enhance or inhibit a response until methods are available for controlling or measuring quantitatively each source of such effects. Meanwhile the task of the experimentalist must be to isolate little by little all variables which reveal additional lines of cleavage or further identities in response characteristics. As these variables are more adequately controlled we shall be in a better position to say which cases of 'extinction' are similarly determined. Until then, the term, extinction, properly and justifiably refers only to the functional relation between a situation defined in terms of observable phenomena and the course of observable response.

Summary

1. *The Experiment.*—40 subjects learned nonsense syllables by the anticipation method and the latency of the second member of each pair in response to the first, was recorded. Each initial syllable of the experimental pairs was then repeated 50 times alone by the experimenter without the presentation of its paired associate: (*a*) in Group I with no instructions; (*b*) in Group II with the repetition of initial instructions, 'to pronounce the syllables appearing in the apparatus.' Latencies of control and experimental syllables were tested immediately after extinction and 24 hours later.

2. The *results* reveal the following phenomena which are apparently analogous to certain characteristics of the conditioned response: (*a*) Syllables put through extinction procedure showed for both Groups a greater number of syllables

forgotten and a more marked increase in the latency of syllables not forgotten, than did control syllables. (*b*) In Group I there was some evidence of spread of this inhibitory effect to control syllables, a phenomenon possibly analogous to secondary extinction. (*c*) After the passage of 24 hours the effect of the non-reinforced repetition tended to disappear so that control and experimental syllables were close together both in terms of the syllables forgotten and the latencies of the remembered syllables.

3. *It is concluded:* (*a*) If extinction be defined as a response decrement incident to the repetition of a secondary (conditioned) stimulus without the primary (unconditioned) stimulus, an extinctive process has been demonstrated to be operative in the verbal reactions to the verbal stimuli of the present experiment. (*b*) This, however, does not constitute a demonstration of the basic identity of the processes responsible for such decrement in the various situations in which it has appeared. Their fundamental nature may as yet only be surmised. (*c*) Proffered explanations of extinction in terms of Pavlovian inhibition, general inhibitory set, and inhibitory conditioning are discussed briefly and suggestions are made indicating the probable complexity of the factors causing decrement.

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THE RELATION OF MAGNITUDE OF GALVANIC SKIN RESPONSES AND RESISTANCE LEVELS TO THE RATE OF LEARNING *

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PART I: THE RELATION BETWEEN MAGNITUDE OF GALVANIC SKIN RESPONSES AND SERIAL ORDER OF LEARNING

Introduction

The principles of primacy and finality in relation to rate of learning have been brought out in many studies. Robinson and Brown (1) found definite evidence of the efficacy of these principles in the learning of lists of 6, 9, 12, 15 and 18 nonsense syllables. Warden (2) found that the principles of primacy and finality are applicable to stylus maze learning as well as to memorizing. This practically universal finding that the first and last items of a series to be learned are learned first has brought forth many theoretical explanations. One explanation is that the first items are free from proactive interference. Another possibility is that the first and last items of a series receive more attention because of their temporal and spatial location, or for some other reason. Hull (3) has postulated an elaborate 'goal gradient' hypothesis based on conditioning, which Hunter has supplemented by postulating two gradients, a forward moving gradient, and a backward moving gradient. Tolman (4) has postulated his concept of 'means-end-readiness.'

Experimentation on the relation of galvanic skin responses to learning has been very meagre and has usually dealt with other aspects of learning, such as relation to affective tone in

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The author wishes to express his gratitude to Dr. A. G. Bills for his helpful advice on the problem, Dr. Harvey A. Carr for his critical reading and suggestions on the original manuscript, Dr. N. Kleitman for his kind permission to use the apparatus, and to S. Titelbaum for his help with the apparatus and experiment.

learning, than that aspect with which this problem is concerned. Whately Smith (**5**) reports that words that elicited a definite galvanic skin response were either learned more rapidly or less rapidly than words that produced no or little skin response. Balken (**6**) failed to corroborate these findings. Likewise numerous experiments have been done in which galvanic skin responses were obtained in the solving of arithmetical and other problems; chief among these is Sears' (**7**).

Several experimenters have shown that the galvanic skin response is related to sweat gland activity (**8**). Richter (**9**) and Schlif and Schuberth (**8**) have shown that the plantar skin resistance is dependent on intact sympathetic nerves, and Richter (**10**) says, "It is now well established that the system necessary for the production of the reflex is located in the cord rather than in any supra-segmental or cranial parts of the central nervous system." However, Foa and Peserico (**8**) conclude, on the basis of their experiments, that the psychogalvanic reflex travels centrifugally over the autonomic fibers, that sectioning of the lower bulb of the medulla abolishes the reflex with stimulation arriving over any sensory nerve, and that the center of the psychogalvanic reflex is located in the corpora quadrigemina and the apex of the calamus scrittorius. Richter (**11**) reports that, "These changes (resistance levels) are further correlated with the mental condition of the individual, varying with degrees of tenseness or strain, with sleep and with all other diurnal changes in mood or disposition."

Darrow (**14**) maintains that the galvanic response is a genetically adaptive reflex for manipulation in startling situations. He says, "We would suggest further, that differences between the reactions of the palms and the backs may be genetically explained by the hypothesis that sweating on the palms and soles may also perform a function relating to the self-preservative, manipulative and perceptual functions." Darrow and Freeman (**15**) further say that, " . . . the relative magnitude of galvanic reactions in palmar and nonpalmar areas is determined by the type of activity giving

rise to the change. It is shown that situations favoring an increase in the subject's anticipation, alertness, or apprehension . . . are likely to be attended by marked increase in conductance of the palm . . . and perspiration . . . on the palms and soles . . . is psychologically significant because it is normally called forth in situations demanding alertness in the mobilization of the energies of the organism for emergency adjustive response." According to these writers, then, the galvanic response is a measure of apprehension, anticipation, awareness, alertness, or attention.

The problem with which the present study is concerned is the relation of the galvanic response evoked by a particular nonsense syllable to the readiness with which that syllable is learned. When the affective element and all other variables associated with the nonsense syllable are controlled except the serial order, are those items which result in the greatest galvanic response learned first or vice versa? If we accept Darrow's contentions (**14** and **15**) as above, then we can say that the galvanic response is a measure of alertness, awareness, apprehension, or attention. This problem, then, is the relation between attention or apprehension as measured by changes in resistance levels to the serial order of learning nonsense syllables, or the principles of primacy and finality. Do these principles hold because of greater attention on the part of the individual to the first and last portions to be learned, and, if so, why does he attend to the first and last portions more than the middle items, and hence learn them first?

Apparatus

The apparatus consisted of two units, the exposure unit and the recording unit. The exposure unit was a Chicago Memory Drum modified so that the duration of each presentation of each item was eight seconds instead of the usual two and modified so that each new presentation of a nonsense syllable was recorded automatically on the photographic record. The duration of presentation of each syllable was lengthened from two seconds to eight seconds, because of the rather long latent period of the psychogalvanic response and in order to make it possible to associate any particular galvanic response with a particular nonsense syllable that may have been involved in evoking that response. The second unit of the apparatus consisted of a Darrow Behavior Research Photopolygraph (**16**) with instruments used to measure blood pressure, respiration, galvanic skin resistance, and preipheral vasomotor changes; this apparatus recorded these changes automatically on a moving photographic film, giving permanent records.

Subjects

Fifteen graduate and medical students served as subjects for the experiment.

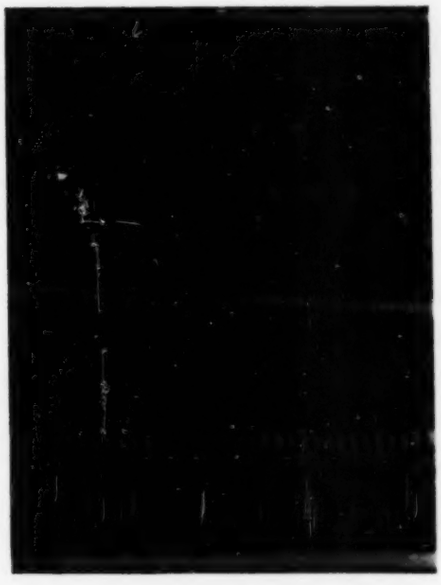
Procedure

The subject, after preliminary instruction as to the nature of the experiment (the instruction being the same for each subject), was strapped in the apparatus. In order to familiarize the subject with the task, he learned a list of 9 syllables, no records being taken. Then the apparatus was connected and a control record was taken with no memorizing, with no syllables being presented, and with the subject resting quietly. Then the memory drum was started and the subject learned the 19 nonsense syllables, using the anticipation method, until one completely successful trial. Continuous records were taken.

In order to eliminate the factor of associational value, a list of syllables was selected from Glaze's (12) list of 0.00 percent associational value nonsense syllables. Nineteen syllables were used, with an eight second exposure for each on each trial. Consequently, on this particular memory drum, there was no greater time between trials than there was between each nonsense syllable. A mark on the memory drum preceding the first item of the list indicated the spatial location of the end and of the beginning of each trial. The experimenter managed the operation of the apparatus while an assistant took down the anticipations of the subjects. Each new presentaiton of a nonsense syllable was recorded automatically on the film in order that any particular galvanic response could be associated with a particular syllable. Gross resistance changes, necessitating changes in the resistance box in order to keep the galvanic needle on the film, were adjusted by the experimenter.

Sample records are presented below. All are from the same subject, and records two, three and four came from the same subject on the same trial.

RECORD 1. Control record—no learning of nonsense syllables taking place. Subject L.



——————Automatic signal key

——————Plethysmograph

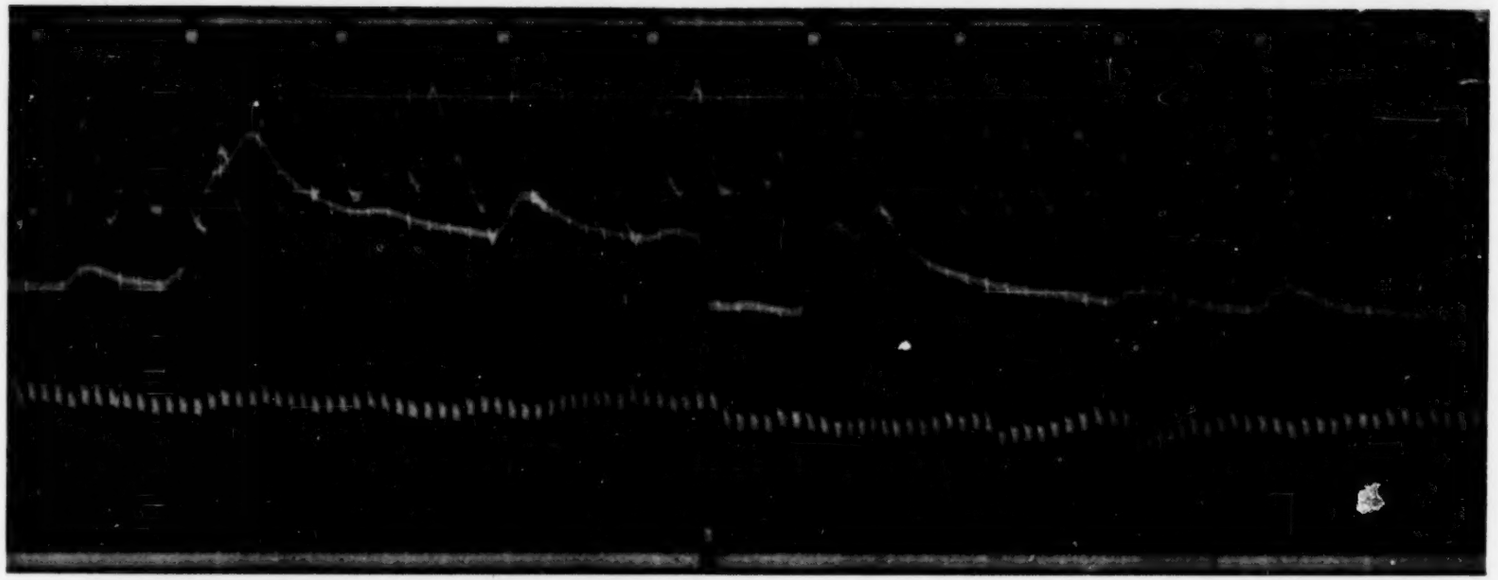
——————Respiration

——————Galvanic

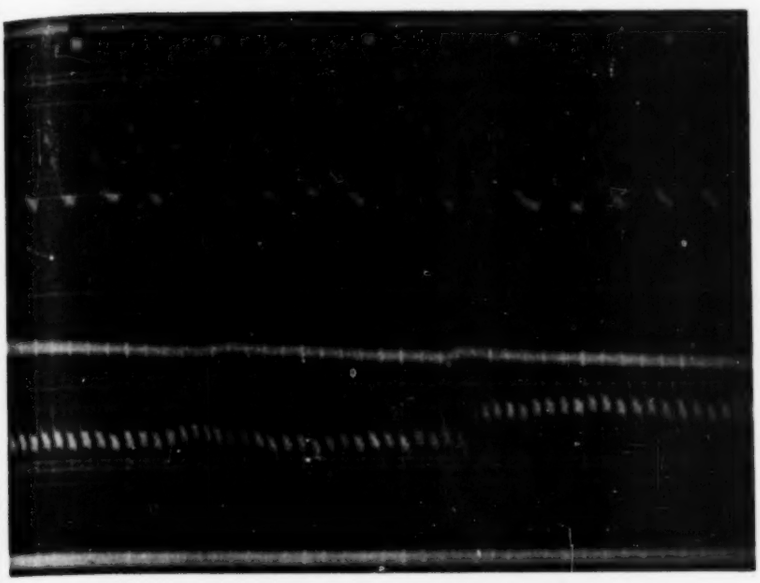
——————Blood pressure

——————Manual signal key

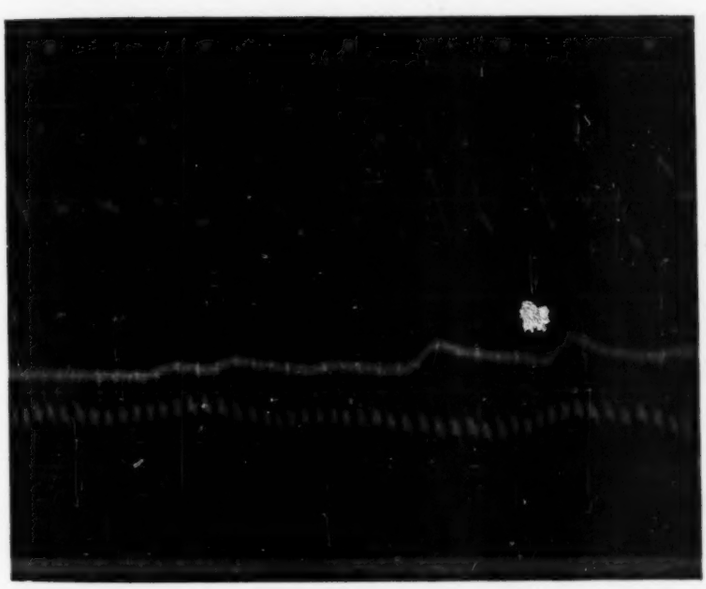
RECORD 2. Last three syllables, trial 4, and first seven syllables, trial 5. Subject L.



RECORD 3. Syllables 10–14, trial 5. Subject L.



RECORD 4. Syllables 15–19, trial 5. Subject L.



Results

Sample records are presented on page 265 ff. It can be seen from the sample records that the control record (Record 1), with no learning taking place, shows a galvanic line with no deflections on it. Records of the beginning and end of trials (Records 2 and 4) have fairly wide excursions of the galvanic

needle. A record of the middle of the same trial has few galvanic responses present. Related to learning, we find that this subject learned the first items of the series first, then the last items, and last of all those syllables in the middle; and in these records we see greater galvanic skin changes at the beginning and end than in the middle. From these records it appears that there is some relation between galvanic skin response per syllable and the order of learning that syllable in serial order memorizing.

As explained above, any particular galvanic response could be associated on the record with a particular nonsense syllable. The method of analysis of the results was to go through the film for each subject and measure the galvanic deflections that occurred for each syllable for each trial. The deflections for each item were then averaged for all trials, so that each nonsense syllable had a certain magnitude of galvanic deflection associated with it for the entire learning series for each subject. These summed galvanic deflections per nonsense syllable were then ranked so that the syllable with the greatest magnitude of galvanic deflection received a rank of 1, that syllable with the least received a rank of 19. The rank for each item was then summed for the group. These data are presented in Table 1.

The number of correct anticipations per nonsense syllable for each individual were counted and they too were ranked so that the syllable with the greatest number of anticipations received a rank of 1, and that syllable with the fewest anticipations received a rank of 19. In other words, that syllable with the most anticipations is said to be learned first, that syllable with the fewest anticipations associated with it being learned last. The number of anticipations per syllable is taken to represent the order of learning of the syllable. Table II presents these data.

A rank order correlation is run for each individual between the ranking in galvanic deflections per syllable and order of learning of that syllable per individual. Rho is converted to *r* from Garrett (13). Table III presents correlations obtained in this way for each of the subjects.

TABLE I

RANKINGS OBTAINED IN MAGNITUDE OF GALVANIC SKIN RESPONSE PER NONSENSE SYLLABLE

Low Ranking Indicates Greatest Response

Serial Order of Nonsense Syllable	Subjects															Total
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	
1	1	3	1	6	1	3	1	3	1	2	7	1	4	1	1	36.0
2	4	10	2	10	13	9	7	5	4.5	10	5	7	5	2	2	95.5
3	7	8	10	11	10	5	9.5	2	7.5	19	1	3	2	10	5	110.0
4	4	14	3	1	12	2	12	13	9	7	10	17	16	4	3	127.0
5	16	12	9	15	4	19	15	19	2	18	4	15	14	13	4	179.0
6	8	18	16	19	6.5	13	13	12	6	16	3	9	15	17	9	180.5
7	15	4	7	18	16	17	9.5	6	3	14	13	14	11	18	14	179.5
8	4	5	17	12	18	7	14	7	12	13	12	10	8	5	10	154.0
9	18	6	14	13	8	18	19	17	15	6	6	8	7	7	18	180.0
10	19	9	11	2	17	1	16	14	18	11	16	6	12	11.5	17	180.5
11	14	17	6	16	11	8	17	16	10.5	9	18	12	6	8	7	175.5
12	10	19	4	9	5	10.5	18	4	19	8	17	16	10	9	15.5	174.0
13	10	16	12	7	14.5	12	11	15	15	3	14	13	17	6	6	171.5
14	12	2	18	14	19	6	6	9	15	12	15	19	19	19	8	193.0
15	13	13	15	8	3	4	2	18	17	5	8	18	18	3	12.5	157.5
16	10	11	19	17	14.5	16	8	8	10.5	15	19	4	3	15	12.5	182.5
17	17	15	5	4	9	10.5	5	10	13	4	11	11	13	14	15.5	157.0
18	6	7	13	3	6.5	14	4	11	4.5	17	9	5	9	16	19	135.0
19	2	1	8	5	2	15	3	1	7.5	1	2	2	1	11.5	11	62.0

TABLE II

RANKINGS OBTAINED IN ORDER OF LEARNING

Low Ranking Equals Greatest Number of Anticipations

Serial Order of Nonsense Syllable	Subjects															Total
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	
1	1	6.5	2	1	1	3.5	1	8.5	1.5	1	1	1	4	3	1.5	37.5
2	3	4	7	3.5	4.5	1.5	2	1	11	3.5	2	2	1	1	1.5	48.5
3	3	2	6	5.5	12	8	4	4	5	3.5	6	8	2	11.5	3	83.5
4	6	8	18	12	13.5	1.5	3	4	1.5	3.5	12.5	14	5.5	5	4	112.5
5	7.5	13.5	11.5	11	7.5	3.5	6	8.5	6.5	8.5	19	3	13	6	7.5	132.5
6	13.5	15.5	13	5.5	3	5.5	9	15	3	12.5	8.5	14	15	2	7.5	142.5
7	15	9	11.5	13.5	19	8	8	12	5	8.5	12.5	10	13	14	11	170.0
8	10	10	5	15	15.5	5.5	15	17.5	5	14.5	6	4	7.5	7	17	154.5
9	13.5	13.5	16.5	19	15.5	8	13.5	17.5	17	6	18	8	9	11.5	12.5	199.0
10	16	11.5	16.5	16.5	13.5	11	17	4	11	14.5	16	11	17.5	4	19	199.0
11	19	15.5	16.5	13.5	18	13	13.5	8.5	19	10.5	16	16.5	13	11.5	15	219.0
12	17	18	16.5	16.5	4.5	11	12	4	13.5	19	12.5	6	10	8	18	186.5
13	18	19	1	9	17	11	17	15	15.5	10.5	10	14	17.5	9	14	197.5
14	11	17	19	18	11	14.5	17	19	18	17.5	16	16.5	19	17	16	246.5
15	12	11.5	9	9	9	16	10.5	12	7.5	17.5	12.5	18	5.5	11.5	5.5	167.0
16	7.5	6.5	9	7	6	14.5	17	15	15.5	16	8.5	19	15	17	5.5	179.0
17	9	4	9	2	10	17.5	10.5	8.5	13.5	17.5	6	12	11	19	10	160.5
18	5	4	3.5	9	7.5	17.5	7	12	11	7	3.5	8	7.5	18	12.5	133.0
19	3	1	3.5	3.5	2	19	5	4	9	3.5	3.5	5	3	15	9	89.0

TABLE III

CORRELATIONS BETWEEN MAGNITUDE OF GALVANIC RESPONSES AND THE ORDER OF LEARNING OF THE SYLLABLES

Subject	r	P. E. r
A	.67	.089
B	.46	.121
C	.14	.147
D	.21	.145
E	.57	.102
F	.16	.147
G	.42	.123
H	.35	.132
I	.53	.108
J	.16	.147
K	.32	.135
L	.42	.123
M	.56	.103
N	.56	.103
O	.61	.096

Graph of the total rankings of all the individuals, in galvanic deflections and rate of learning, as measured by the number of correct anticipations, per nonsense syllable. The nonsense syllables were ranked so that the syllable with the greatest galvanic deflection receives a rank of one, and the syllable with the greatest number of correct anticipations likewise receives a rank of one.

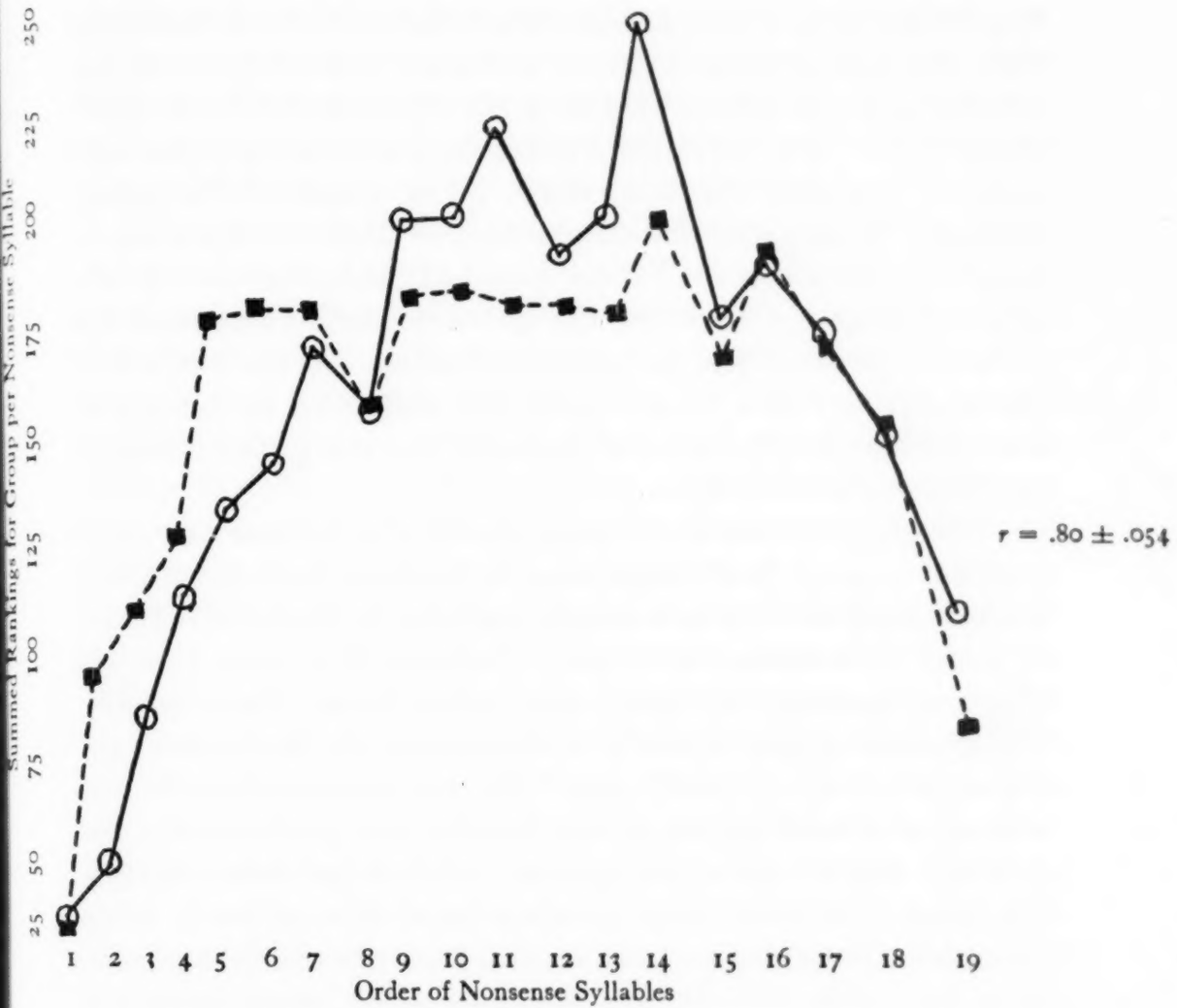
Key: ⊖——⊖——⊖ Total rankings of all the individuals in respect to efficiency of learning per nonsense syllable. ■- - -■- - -■ Total rankings of all the individuals in respect to the magnitude of galvanic deflection per syllable.

A graph of the total rankings of all the individuals in galvanic deflections and order of learning the nonsense syllables is presented. The correlation between these summed totals in respect to galvanic deflections per nonsense syllable and the order of learning that syllable was found to be $.80 \pm .054$.

When the galvanic responses are averaged for each trial up to and including the first correct anticipation for each syllable, we get a group correlation of $.81 \pm .051$ between the magnitude of the galvanic response per syllable and the order of learning of that syllable.

When the galvanic responses associated only with correct anticipations are averaged for each syllable, we get a group correlation of $.58 \pm .10$ between the magnitude of galvanic response per syllable and the order of learning of that syllable.

Analyses of the blood pressure, respiration, and plethysmograph records for eight subjects failed to give any consistent results, so further analysis of these measures was not done.


Summed Rankings for Group per Nonsense Syllable
25 50 75 100 125 150 175 200 225 250
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
Order of Nonsense Syllables
r = .80 ± .054

Discussion of Results

The correlations for each individual between the summed galvanic deflections per syllable and the order of learning of that syllable are in general quite high for biological correlations of this sort, as can be seen from Table III. While all of the correlations are not statistically significant and while there is a great deal of variability in the correlations, nevertheless because of the fact that all are positive and there are several that are quite statistically significant, we feel safe in concluding that there is apparently some relation between the magnitude of the galvanic deflection and the order of learning nonsense syllables. The close relation, as revealed by the records for the group, between the total summed rankings in order of learning (Table II) and the total summed rankings

in galvanic deflections per nonsense syllable (Table I) indicates that this relationship between galvanic skin deflections per syllable and the order of learning the items in the list is much closer when individual differences in galvanic response and order of learning are minimized. The graph of the group rankings in galvanic deflections and in order of learning (a graph of the totals in Tables I and II) indicates clearly the close relationship between the galvanic deflections and the order of learning the nonsense syllables. A correlation of .80 ± .054 between the galvanic skin deflection rankings and the rankings on the order of learning for the group is highly significant statistically.

The graph presented further shows that primacy of serial position is more facilitative than is finality, and that finality is more facilitative than a middle position in the serial learning of a list of nonsense syllables. Further, it is seen that the effect of primacy extends over more items than finality. These results are directly comparable to Robinson and Brown's (1) who found that, "In our experiments the advantages of both primacy and finality are pronounced; and primacy shows an even greater advantage than finality. We have also been able to show that this primacy effect extends in some degree over several items in the first portion of a list, while the finality effect is much more limited in scope." Similarly, the galvanic deflections are greatest for the first items. The galvanic deflections are likewise greater for the last items than they are for the middle ones.

The results show that the galvanic deflections that were associated with those trials in which the subject made the wrong or no anticipation were greater factors in our correlations between the total magnitude of galvanic responses per syllable and the order of learning, than were the galvanic responses associated with those trials in which the subject made the correct anticipation. This is evident from the fact that we obtained a correlation of .81 for those trials in which the subject made no or the wrong anticipation while we obtained a correlation of .58 when the subject made the correct anticipation. Greater deflections are obtained in those trials

in which the anticipations are either wrong or in which the subject is unable to make any anticipation than in those trials in which the correct anticipation is made. This means, then, that greater deflections are associated with the learning of a syllable than with its correct anticipation.

The interpretation of these results must be drawn cautiously. Darrow (**14**) maintains that the galvanic reflex is a genetically adaptive reflex for manipulation, etc., in startling situations and that it measures apprehension or alertness. Darrow and Freeman (**15**) say, " . . . The relative magnitude of galvanic reactions in palmar and non-palmar areas is determined by the type of activity giving rise to the change. It is shown that situations favoring an increase in the subject's anticipations, alertness, or apprehension . . . are likely to be attended by marked increase in conductance of the palm . . . ." If we accept Darrow's contention that the galvanic response is a measure of apprehension, alertness, or attention, then it would seem evident that the subjects learn the first items first because they attend to them more than they do to the middle items. This is evident from the findings that the first items evoked greater galvanic skin responses than the other items. Similar conclusions can be drawn in respect to the last items of the series; the subject may learn the last items before he learns the middle ones because he attends to those last syllables more than he does to the middle items. If this is true, we can ask the question, "Why do the subjects attend to the first syllables more than the last ones, and the last items more than the middle ones, in a serial learning problem?" Logically the attention compelling factor of serially placed items could be a temporal affair and the explanation might be that the first and last syllables are free from proactive and retroactive interference. However, in this study the temporal element was purposely ruled out by having the same time interval between trials as existed between the presentation of each nonsense syllable. This study shows, then, that the principles of primacy and finality operate in the memorizing of serially placed syllables, because greater attention is applied to items occupying initial and

final positions and not because the first item is free from proactive interference. It further shows that there is increased tension, alertness, awareness, or apprehension on the part of the individual to items occupying initial and final positions in the memorizing of serially placed syllables, resulting in the individual learning these items first.

Part II. The Relation between Gross Resistance Levels and the Efficiency of Memorizing Nonsense Syllables[1]

Richter (16) has found that during sleep there is a large increase in the electrical resistance of the skin. Richter has further found (11), substantiating Vigouroux's (17) work in 1879, that the resistance of hyperthyroid patients is extremely low. Two of our subjects likewise, were mildly hyperthyroid and had low resistances of 6,000 and 12,000 ohms. In sleep the activity of the nervous system is at a minimum; in mild hyperthyroid cases, however, the activity of the nervous system is greater than normal and learning is supposedly more rapid, other things being equal, than in the normal individual. The question arises then, in normal subjects, midway between the two cases mentioned above, is there any relationship between the efficiency of learning and gross resistance level? Richter (11) says that the resistance level of a subject varies, among other things, with the tenseness or strain of an individual, and Darrow and Freeman (15) say that "situations favoring an increase in the subject's anticipation, alertness, or apprehension . . . are likely to be attended by marked increase in conductance of the palm." Stroud (18) has found that increased tension in the muscles on the part of the individual favors more efficient learning. The question arises then as to whether or not there is any relationship between the tension of the individual, as measured by the gross resistance level, and the efficiency of memorizing nonsense syllables as measured by the number of trials required for one successful completion.

[1] A paper dealing with a similar problem was read by M. M. White at the April meeting of the Midwestern Psychological Association.

In this part of the study records were obtained from eighteen subjects, since in the previous study three records were invalidated for that study by the failure of the memory drum to record the presentations of the nonsense syllables. Gross resistance levels were read at the beginning, continuously throughout the experiment, and at the end. Otherwise the conditions were identical with those described on a preceding page.

A correlation of .25 ± .14 was obtained between the resistance at the beginning of the learning situation and the efficiency of learning as measured by the number of trials required for one successful completion. A correlation of .57 ± .10 was obtained between the resistance level at the end of the experiment and the number of trials required to complete the problem. Similarly, we get a correlation of .55 ± .10 between the average resistance level at the beginning and at the end of the problem and the number of trials necessary for completion of the learning. In other words, the lower the resistance level, particularly at the end of the experiment, the fewer trials were required by the subject to complete the problem; this was far from a one to one relation. Then we can say, by and large, that the greater the tension of the individual, the faster he learned. However, in any correlation of this kind there are two things to consider. One is the factors that make for efficient learning of nonsense syllables. Undoubtedly, from the above correlations the tension in the individual is a factor, as is substantiated by Bill's (**18**) and Stroud's (**19**) findings on the relation of muscular tension to the efficiency of learning; however, there are numerous other factors related to the efficiency of learning nonsense syllables such as previous practice, intelligence, or rather, memorizing ability, attitude of the subject, method of attack, etc. Secondly, there are numerous factors that influence the gross resistance level of an individual; Richter (**11**) says; "These changes (resistance levels) are further correlated with the mental condition of the individual, varying with degrees of tenseness or strain, with sleep, and with all other normal diurnal changes in mood and disposition." It must be further

kept in mind that these different authors mentioned above believe that the resistance level within an individual varies, among other things, with his tension or strain, but they do not say that the tension or strain among different individuals is inversely proportional to the resistance levels of those individuals. It must also be kept in mind that the inclusion of a few mild hyperthyroid individuals with low resistance levels and fairly fast learning time will give a spurious correlation between resistance level and efficiency of learning. We did find, as a rule, that the lower the resistance of the individual, the faster he completed the learning of the nonsense syllables; and with the above cautions in mind we tentatively say that the tension of an individual seems to be related to that individual's efficiency of learning nonsense syllables.

Conclusions

1. In this experiment it was demonstrated that the principles of primacy and finality hold in the memorization of serially placed nonsense syllables when the time interval between successive trials is the same as the time interval between each syllable. The primary factor is a stronger factor and extends over more items than the finality factor.

2. The galvanic deflections per nonsense syllable follow closely the order of learning of the nonsense syllables. The galvanic deflections are greatest for the first items, and greater for the last nonsense syllables than they are for those in the middle. The greater galvanic responses extend somewhat farther in a forward direction from the first syllable than they do in a backward direction from the last item.

3. Individual correlations of from .14 to .67 were obtained between the averaged galvanic deflections per nonsense syllable and the order of learning of the nonsense syllables. A group correlation of .80 was obtained between the galvanic deflections for the group per syllable and the order of learning of that item for the group. In other words, there seems to be a fairly close relationship between the serial order of learning of the nonsense syllables in a list and the galvanic deflections each one evokes.

4. When the galvanic responses are averaged for each trial up to and including the first correct anticipation for each syllable we obtained a group correlation of .81 between the magnitude of galvanic response per syllable and the order of learning of that syllable. Greater deflections are associated with the learning of a syllable than with its correct anticipation.

5. The interpretation that these results indicate is that the principles of primacy and finality function in the memorizing of serially placed nonsense syllables, because there is greater attention, tension, awareness, or apprehension on the part of the individual to those items occupying a primary and a final position.

6. A correlation of .25 was obtained between the gross resistance level at the beginning of the experiment and the number of trials required to complete the problem. A correlation of .57 was obtained between the gross resistance level at the end of the experiment and the number of trials required to complete the problem. A correlation of .55 was obtained between the average resistance level at the beginning and at the end of the problem and the number of trials necessary for completion of the learning. We tentatively say that the tension of an individual as measured by his gross resistance level seems to be related to that individual's efficiency of learning nonsense syllables; an interpretation of this sort must be made with extreme caution.

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FURTHER STUDIES ON THE RELATION OF PERSONALITY AND GESTURE. A NOSOLOGICAL ANALYSIS OF AUTISTIC GESTURES[1]

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Autistic gestures is a concept applied by the author to a certain class of differentiated, non-verbal responses (*e.g.*, scratching ear, protruding tongue, wiping dry nose, etc.) in which motivation is obscure and insight lacking. Previous studies have shown that these gestures are unrelated to situations in which they occur, and are traceable to impulses inhibited as a result of conflict (**3**). The impulses, set off by situational stimuli, are symbolically disguised as overt muscle action, instead of being, as is more common, revealed in verbal form. The stimuli do not evoke the verbal connotation of autistic gestures, because it is precisely the impulses leading to the larynx that are blocked and shifted to substitute effector systems.

This is not an attempt to give a particularized account of autistic gestures in terms of typical verbal equivalents—a task reserved for a later date. It is our aim at this time to discover whether or not autistic gestures bear a definite, determinable relation to personality types. Since these gestures are manifestations of previously inhibited impulses, they must exist implicitly as persistent muscle tensions. There can be no persistent tensions, unless they are accompanied by equally persistent conflicts. Persistent conflicts tend toward substantially similar forms of expression. Thus recurrent behavior, the essence of personality types, helps us formulate our problem. Do autistic gestures showing structural and behavioral uniformities offer some cues to typological trends in personalities?

[1] Read at the eleventh annual meeting of the Midwestern Psychological Association, Northwestern University, Evanston, Ill., April 24, 1936.

Two methods were employed in the collection of material. The first consisted in observing college students in the classroom, and recording gestures and stimulus-words preceding them. The length of each observation period was 55 minutes. Two observers were assigned to each subject, and the results were pooled and averaged. The gestures obtained by this method, called *classroom* gestures, served as controls for the gestures obtained by our second method.

Elsewhere described as the mute-association method, this included an association test based on the words recorded in the classroom, and a repetition of the test, modified by the instruction that the subjects respond to the words without verbalizing their associations. Record was kept of the gestures occurring in the course of this inhibited association. The length of each observation period varied according to the number of words involved and the reaction time of each subje . The gestures obtained by this method were called *mute-association*, or experimental, gestures.

Twenty-six subjects—fifteen women and eleven men—were employed in this study.[2] Ten of these were not available for experimental study and furnished only classroom data. There were 203 classroom and 63 experimental observations. The number of classroom, or control, gestures observed was 12,861, and the number of mute association, or experimental, gestures was 9,796, making a total of 22,657 autistic gestures recorded by all observers (Table 1). These gestures were classified under two distinct lists of categories.[3] The first list applied to the moving organ conveying the gesture. The second referred to the goal-organ or goal-object with which the moving organ came in contact.[4]

The list of terms includes, in the order of anatomical position, the following descriptions of moving organs: Cephalic, ocular, lingual, oro-labial, thoracic, upper-appendicular, manual, digital, pelvic, lower-appendicular, pedal, and somokinetic. The latter term has reference to (gross) organismic movements, which are not limited to one special motor organ. To complete the classificatory scheme, we coupled the previous list of terms with another list describing the stationary goal-organs or goal-objects to which moving organs may be directed. This list embraces, in the order of anatomical position: hirsutal, cephalic, facial, ocular, nasal, oro-labial, aural, cervical, thoracic, upper-appendicular, manual, digital, abdominal, genital, pelvic, anal, lower-appendicular, and pedal organs. In addition, we provided three terms for what we designated as environmental goals—physical, social, and personal—and two terms applicable to movements which appeared to be without definable goal-organs or goal-objects.

[2] The data on seventeen of these subjects were also used in a study of the reliability of gesture observations and the consistency of gestures (3).

[3] For a critique of other types of classification see (2).

[4] This does not mean that autistic gestures have at any time a goal which the subject can describe, though *objectively*, of course, he may have one.

TABLE 1

DISTRIBUTION OF SUBJECTS AND OBSERVERS WITH REFERENCE TO TYPE OF OBSERVATION, OBSERVATION FREQUENCY, AND TOTAL NUMBER OF GESTURES OBSERVED

Subject	Control (Classroom) Observations					Experimental (Mute-Association) Observations					Total Observations		
	Observation Periods (by Observer)				Gestures Recorded	Observation Periods (by Observer)				Gestures Recorded	Number of Observation Periods		Combined Totals of Gestures Recorded
	A	B	C	D		A	B	C	D		Control	Experimental	
LA	2	7	8		878				2	395	17	2	1,273
VA	7				438		2			550	7	2	988
UD		6			1,464	2			3		10	5	1,464
BE	1	2	4		640			2	1	553	3	3	1,193
LE	1				247						1		247
PE			6	3	1,120	2	1				9	3	1,120
SE					70	2					2		70
SH	7	4			86			2	2	877	11	4	963
KI	1		1		538		2		2	623	2	4	1,161
MI	7	3	2		1,078					348	12		1,426
FL	6	6			359			4	2	325	12	6	684
OL		7	6		641	2			1	480	13	3	1,121
SM	5			4	686		2	2		496	9	4	1,182
FN	5		5		1,019		2		2	378	10	4	1,397
WN						2	2			770	4		770
GO	5	4			603			2	2	1,242	9	4	1,845
KO	4	2	5	3	750						14		750
NO	3	4			299			1	2	702	7	3	1,001
SO			3	3	341	1	2			622	6	3	963
KP	6	7			848						13		848
WS		9	6	3	217	2			1	622	18	3	839
ET	7	2			373						9		373
WT						2	2			813	4		813
WW	4				236						4		236
MX	1				241						1		241
FX	1	5			689						6		689
Total					12,861					9,796	203	63	22,657

These terms were *somokinetic* and *organokinetic*, the first referring to skeletal movements (such as arm-twisting) and the second to visceral movements (such as coughing).[5]

Classifying the gestures according to this plan, we found 122 possible pairs of organ-types [6] (Table 2). The correlation of paired classroom (control) with paired mute-association

[5] For critical comment on this classification I am indebted to Frederick Steigmann, M.D.

[6] This study is based on 91 such pairs found applicable to our subjects.

TABLE 2

GENERAL SCHEMA FOR CLASSIFICATION OF GESTURES BASED ON MOVING ORGANS AND GOAL ORGANS (OR GOAL OBJECTS) AND SHOWING 122 COMBINATIONS POSSIBLE OF OBSERVATION

	Cephalic	Hirsutal	Facial	Ocular	Nasal	Oro-Labial	Aural	Cervical	Thoracic	Upper Appendicular	Manual	Digital	Abdominal	Genital	Pelvic	Anal	Lower Appendicular	Pedal	Personal Environment	Physical Environment	Social Environment	Somokinetic
Cephalic	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Facial			X			X				X				X								
Ocular				X				X		X				X				X		X		
Lingual					X	X		X		X				X								
Oro-Labial						X		X		X				X								
Organokinetic					X	X		X		X				X		X						
Upper appendicular				X				X		X				X								
Manual								X		X	X			X								
Digital								X		X		X		X								
Pelvic								X		X				X								
Genital								X		X				X								
Lower appendicular																						
Pedal																						
Somokinetic																						

(experimental) gestures was then computed, by the method of rank differences, for each subject for whom both types of data were available.[7] In only one case (F.L.) was the coefficient markedly low, *viz.*, 0.07 ± .11. In another (V.A.) we obtained a high negative correlation, *viz.*, − 0.77 ± .06. On analysis, these proved to be cases in which, probably under the stress of the test situation, the subjects evidenced extraordinary inhibition of some, and a compensatory exhibition of other, movements. In the remaining cases, the correlation of control and experimental gestures has yielded positive coefficients ranging from 0.76 ± .05 to 0.95 ± .01; the modal (and median) correlation coefficient being 0.89 ± .02.

The high correlation of classroom and experimental observations has proved the consistency of autistic gestures, in the face of carefully noted stimuli, in a much more emphatic way than had any of our previously published results. It showed, furthermore, the presence of certain personality trends. The question as to whether the recurrence of the gestures is to be credited merely to the repetition of the stimuli is of secondary importance. We may argue just as reasonably that the consistency observed is due to the consistency of *structural* personality factors. In other words, if responses in similar situations tend to appear similar, it is because there are certain recurrent personality trends which assure their similarity even on a non-conscious level of behavior.

From this we proceeded to study our data in two ways. First, keeping goal-organ constant, we attempted to see what variations would be found in the moving organs. Next, reversing the procedure, we held the moving organs constant, in an attempt to locate trends in goal-organ or goal-object factors present in autistic gestures. In regard to moving organs we discovered a rather concentrated percentage-distribution emphasizing *appendicular* gestures (including in this term not merely movements of arms but also those of legs, feet, hands, and fingers). The predominance of these gestures was indicated by percentages ranging from 46.6 to

[7] The reason for individual correlation was that the *number* of gesture-types varied in each case. See Table 3.

TABLE 3

AN ABRIDGED CLASSIFICATION OF GESTURES IN TERMS OF PAIRED ORGAN GROUPS

Subjects	A. Moving Organs												B. Goals: Organs or Objects															
	Lingual		Oro-Labial, Ocular		Facial, Cephalic		(Lower and Upper) Appendicular, Digital, Manual, Pedal		Pelvic, Organo-kinetic, Somo-kinetic		Miscel-laneous		Social and Physical Environ-ment		Personal Environ-ment		Hirsutal, Cephalic, Facial, Cervical		Ocular, Nasal, Aural, Oro-Labial		(Lower and Upper) Appen-dicular, Digital, Manual, Pedal		Abdom-inal, Genital, Sacral, Anal		Somo-kinetic		Thoracic		Miscel-laneous	
	C	M	C	M	C	M	C	M	C	M	C	M	C	M	C	M	C	M	C	M	C	M	C	M	C	M	C	M	C	M
1. KA		1.1	10.3	8.6	14.4	7.8	60.1	70.1	15.2	12.4	0.0	0.0	16.0	23.1	4.9	9.4	7.4	5.6	7.0	3.0	0.5	10.8		1.5	43.6	37.7	13.7	4.1	6.9	4.7
2. LA	1.8	0.6	5.2	9.2	10.2	6.0	74.1	75.6	8.7	8.6	0.0	0.0	38.0	28.6	4.9	2.9	9.9	2.9	4.9	2.1	19.9	14.8	0.6	0.0	19.5	46.1	0.3	2.1	2.0	0.5
3. VA	0.4	8.0	0.8	0.6	14.0	3.8	71.5	79.4	11.0	6.9	2.3	1.3	25.7	61.2	0.8	0.6	14.5	2.2	7.4	10.9	10.5	2.8			33.3	19.1	2.5	1.9	5.3	1.3
4. UD	0.3	0.6	6.6	5.5	6.1	6.2	76.2	80.6	10.5	5.5	0.3	1.6	17.2	22.5	5.7	1.8	19.2	9.3	9.0	4.7	10.5	13.6	0.3	1.2	31.4	41.1	2.9	1.8	3.8	4.0
5. BE	1.9	2.8	9.9	11.7	11.4	3.7	69.2	67.5	7.6	11.2	0.0	5.1	31.0	31.8	5.3	2.5	9.9	12.0	18.7	7.4	14.5	5.4		0.2	10.7	30.4	9.9	6.8		3.5
6. LE	5.3		8.9		8.0		63.3		14.3		0.2		39.6		6.7		7.6		8.8		5.4		0.6		29.8		0.6		1.9	
7. PE	0.6	0.3	3.8	4.5	17.2	12.5	77.4	70.1	1.0	9.8	0.0	2.8	19.5	28.6	12.2	12.2	21.3	12.6	11.9	9.0	12.8	5.3		5.5	14.5	24.1		0.5	4.8	2.2
8. SE								73.9		24.5		1.6	16.5		23.6		13.5		5.3		24.5		1.3		13.8				1.5	
9. SH			3.6	5.9	19.4	4.9	60.4	78.9	16.5	9.8	0.1	0.5	43.8	27.1		1.6	14.5	17.1	7.2	8.2	1.2	9.3	3.6		26.6	30.7	2.4	5.7	0.7	0.3
10. MI	0.9		5.1		14.6		71.0		8.2		0.2		39.6		6.7		7.6		8.8		5.4		0.6		29.8		0.6		1.9	
11. FL	0.0	0.0	7.2	6.0	7.8	6.6	62.4	26.0	22.3	60.3	0.3	1.1	26.9	66.6	0.6	1.0	24.3	1.0	15.1	7.2	9.2	5.3			21.0	12.0	0.7	4.4	2.2	2.5
12. OL	1.2	1.1	2.1	9.5	17.8	11.0	61.8	66.1	16.2	11.0	0.9	1.3	33.0	20.1	4.2	6.3	13.3	14.1	19.0	10.6	6.9	4.1	0.3	0.4	22.4	41.4	0.9	2.1	0.0	0.9
13. SM	0.0	0.3	1.9	6.9	11.0	11.7	74.1	68.3	10.4	9.0	2.6	3.8	23.5	20.0	0.5	0.9	11.0	10.4	23.9	8.4	11.6	2.2	0.6	0.3	24.7	40.6	2.9	2.3	0.3	4.9
14. FN	2.0	6.3	10.5	10.1	17.0	6.9	55.1	65.1	15.4	8.0	0.0	3.6	20.2	32.8	3.6	3.8	13.7	6.3	10.1	0.4	11.3	20.7	1.2	1.4	33.2	26.9	0.8	3.8	5.9	3.9
15. WN		1.3		19.9		9.5		60.8		6.4		2.1		37.8		0.4		6.5		6.3		5.9		0.4		36.4		4.2		2.1
16. GO	3.7	1.2	7.2	4.5	25.8	5.7	46.6	80.7	16.5	7.7	0.2	0.2	19.9	30.0	5.0	2.4	8.4	15.4	16.1	18.3	8.4	8.6	0.3		38.9	23.1	2.1	1.8	0.9	0.4
17. KO	2.8		2.8		10.4		72.3		10.4		1.3		36.1		5.7		9.5		11.4		11.4		0.9		23.8		0.9		1.3	
18. NO		0.7	0.7	12.8	38.6	15.3	50.0	62.0	11.2	8.5	0.1	0.7	12.7	21.3	7.7	2.1	11.2	4.9	4.9	5.3	5.0	16.3	0.7	1.0	54.2	43.3	0.7	4.9	2.9	0.9
19. SO	0.0	0.4	4.1	7.4	13.3	8.9	74.0	75.8	7.4	3.4	0.2	4.1	28.2	29.4	9.1	3.5	11.5	5.5	10.6	6.9	12.3	27.2		1.3	19.0	23.9	1.6	0.8	7.7	1.5
20. KP	0.4		5.6		22.6		53.0		18.3		0.1		30.1		3.9		9.5		5.6		3.5		0.2		40.9		0.5		5.8	
21. WS	0.9	3.3	14.6	28.3	36.6	17.3	36.6	39.4	11.0	11.5	0.3	0.2	16.6	18.2	4.5	0.9	2.7	4.8	5.5	8.1	6.4	4.8			49.0	57.2	4.5	5.2	0.3	0.8
22. ET			6.2		21.9		69.9		2.0		0.0		32.8		7.6		14.6		5.5		18.1		0.6		19.5		0.6		0.7	
23. WT		0.3		2.5		4.9	78.5			10.3		3.5		42.2		0.6		10.7		12.9		4.9		0.3		23.4		1.5		3.5
24. WW			2.9		22.7		55.7		16.1		2.6		28.4		3.7		9.7		6.4		3.3				44.8		1.1		2.6	
25. FX	0.9		7.6		4.6		69.8		14.2		2.9		19.8		5.5		22.0		11.9		8.9				23.4		5.6		2.9	
26. MX	0.3		5.5		29.8		48.9		13.5		2.0		2.2		5.0		2.3		8.9		5.7				53.6		0.3		1.8	
27. FY	0.8		9.8		5.4		71.6		10.3		2.1		11.8		15.5		10.3		6.0		16.6				36.0		1.7		2.1	
Total	24.2	28.3	142.9	153.9	400.6	142.7	1603.5	1140.3	288.2	224.8	18.7	33.5	629.1	541.3	152.9	52.9	327.4	141.3	249.9	129.7	243.8	162.0	11.8	13.5	757.4	557.4	57.8	57.9	66.2	37.9

C = classroom (control); M = mute (experimental).

77.4 (Table 3). In only one case have we found a scatter of percentages showing overlapping validity of several moving-organ groups. Ranked in the order of frequency, the moving-organs gave us the following sequence: (1) appendicular, (2) facial-cephalic, (3) somokinetic and organokinetic, (4) oro-labial-ocular, and (5) lingual.

On assuming the constancy of *moving* organs, we discovered that the distribution of percentages, in the case of goal-organs and goal-objects, was far more even and diffuse than in the case of moving organs. No figure here exceeded 54.2 percent of the total for a given subject, and in most cases the dominant percentages did not exceed a third of the total (Table 3). The ranking order of frequency for the goal-groups was (1) somokinetic, (2) environmental—physical and social, (3) appendicular, (4) facial-cephalic, (5) ocular-oro-labial-nasal-aural, (6) environmental—personal, (7) organokinetic (thoracic), and (8) abdominal-anal-genital. It is of interest to note that 44 percent of our subjects were predominantly somokinetic, or directionless, in their autistic motor outlets; 41 percent predominantly environmental (physical or social); and 15 percent showed equal frequency of both types of expression. Whether this constitutes a confirmation, on a non-conscious, non-verbal level, of the classification of personalities into extravert, introvert, and ambivert can not be said conclusively at this point.

Certain marginal cases have led to further findings. In the study of moving-organ dominance we found a case which favored the somokinetic (or total-organismic) type of movement, in the experimental series, and the appendicular in the classroom series. The difference appeared important. We noticed that the balance in favor of somokinetic movements was offset by the difference between the two series in the appendicular group. This led us to suspect that, in the experimental situation, inhibited appendicular movements led to total-organismic motor-storms. In two other cases, however, we found that the difference between the appendicular-experimental and appendicular-control groups might be divided evenly between somokinetic and facial-cephalic movements.

In the study of goal-organs and goal-objects we found, in several instances, similar disparities for control-somokinetic and experimental-somokinetic movements. The increase in somokinetic movements, in the experimental series, was here again offset by a corresponding decrease in the appendicular or the oral-ocular-nasal-aural grouping, supplemented, to some extent, by other goal-types, especially the environmental and the facial-cephalic. Thus the relationship proved similar to that prevailing in the moving-organ analysis. Appendicular-control gestures observed in the classroom were supplanted by total organismic movements in experimental situations. Again, movements directed to parts of the appendicular skeleton, in the classroom, were replaced, in the experimental situation, by total organismic goal-less movements, accompanied by ocular-oral-nasal-aural gestures as a secondary goal-group.

In view of the consistency found for the entire universe of gestures, the deviations observed may be assumed to show definite personality trends. One of these is that appendicular organs may be replaced by somokinetic, facial-cephalic, ocular-oral-nasal-aural movements, or a combination of any two of these, exactly to the extent to which the appendicular group is inhibited.[8] The group by which the basic appendicular types are replaced, either as goals or as moving organs, may be a personality factor of considerable importance, but our study did not cover this point.

Summary

The findings of this investigation may be summarized as follows:

1. The recurrence of autistic gestures as group-movements, facilitated by certain organs and directed to definite ends, may be expected with a high degree of certainty.

2. Appendicular organs—arms, hands, legs, feet, and fingers—constitute the organs which are most frequently in motion in autistic gestures. This is in contradiction to

[8] Compare this conclusion with the previously formulated conclusion in regard to *primary* or direct and *secondary* or indirect gestural responses (4).

certain studies (**1**, **5**), indicating that facial movements are the most frequent.

3. From the point of view of direction, somokinetic (or gross goal-less) gestures show greatest frequency; physical and social objects being second in defining the direction of autistic gestures; and a mixture of environmental and somokinetic movements being of least frequency among the subjects studied.

4. In spite of the remarkable consistency discovered for organ-groups generally, there is some indication, from a small number of cases, that, in case of inhibition, both moving organs and goal-organs may change; the trend being from appendicular toward somokinetic and facial-cephalic movements, especially.

5. The nosological framework presented here merely utilized the obvious fact that a gesture proceeds from somewhere to somewhere, unless it is organokinetic or somokinetic in nature. The results of the study based on this framework appear to lend point to the hypothesis that autistic gestures belong among those persistent behavior-patterns which, objectively speaking, constitute personality.

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AMOUNT OF MATERIAL AND DIFFICULTY OF PROBLEM SOLVING. II. THE DISC TRANSFER PROBLEM

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A puzzle described by Peterson [1] has certain advantages as material for investigating the relation between complexity of problem and difficulty of solution. This puzzle consists of blocks of different sizes, and a board marked in three positions: A, B, and C. The blocks are placed one upon another at position A in order of decreasing size from the bottom up. The solution consists in moving the blocks from A to B in the fewest possible moves (using C as a way station when necessary), moving one block at a time and never placing a larger block upon a smaller.

The disc transfer problem meets two conditions considered essential in the present study. (1) Increase in the number of moves changes the problem quantitatively but not qualitatively. With the exception of one move that is a constant factor in all problems, increasing the number of blocks by one merely doubles the minimum number of moves required. Thus the 'basic' 7 moves in the 3 block problem include two 2 block problems: moving the upper pair of blocks from A to C and again from C to B, with one move (base from A to B) between. Similarly the 4 block (15 move) problem may be solved by disregarding the base and moving the other three blocks from A to C and afterwards from C to B, with the move 'base from A to B' interposed between these two parts of the problem. It follows (especially since moving the base from A to B offers no difficulty once the other blocks have been placed on C) that any disproportionate rise in difficulty with increase in the number of elements must be due to increase in difficulty of organizing the pattern. (2) Secondary perceptual

[1] Peterson, J., in *A Handbook of Child Psychology* (C. Murchison, Ed.), Clark Univ. Press, 1931, pp. 367–370.

aids are deleted. The problem is temporal and only unfolds move by move, each change abolishing the preceding pattern. The only way in which a subject could obtain secondary perceptual aid would be through recording each move as made and studying the record.

It is of course true that a single principle governs problems of whatever complexity, and it is theoretically possible to effect an a-priori analysis of the problem, and, after generalizing the principles involved and formulating them in words, to apply these principles to problems of any size. But this is no objection from our point of view, since one important aspect of the investigation is the relation between size of pattern and difficulty of abstracting and generalizing. In fact, however, only two subjects of the one hundred and fifty used in the present experiments discovered the key.

The board used in our work was ¾ inch pine 4 × 7 inches. The blocks, ¼ inch thick, were cut from chair dowels three-quarters, five-eighths, one-half, and three-eighths inches in diameter, and were blackened by dipping in ink.

Experiment I

Method of Equated Groups

The subjects for the first experiment were ninety-one members of the class in introductory psychology at Acadia University. These were divided into three groups equated from scores on the Carnegie Mental Ability Test. Group I (14 girls, 14 boys) solved the 2 block (3 move) problem, Group II (14 girls, 17 boys) the 3 block (7 move) problem, and Group III (15 girls, 17 boys) the 4 block (15 move) problem.

At the beginning of an experimental session a subject was seated before the puzzle board (placed on a table at a convenient height) and asked to read the following typewritten instructions:

> "Reproduce the pattern now at A on B. Use C as a way-station when necessary.
> "Never place a larger block upon a smaller.
> "The problem is solved when you can reach the goal in (3, 7, 15) moves."

After ample time had been allowed for studying the instruction sheet, the 'rules of the game' were rehearsed verbally and illustrated by the experimenter moving the four pieces used in the 15 move problem into various positions.

In the experiment proper the moves were counted, and time was measured by a stop-clock recording half-second intervals. Another stop-clock was used for timing the thirty second intervals that elapsed between trials. To lessen the probability of a subject attempting to analyze the problem during these rest intervals, the blocks were removed from the board at the end of a trial and replaced immediately before the next. The criterion of learning was one perfect trial, *i.e.*, a trial in which the goal was reached in the fewest possible moves.

Four measures are presented in Table I: errors, moves, time and trials. The error measure was obtained by counting only the moves in each trial in excess of the smallest possible number (3, 7, or 15), and is thus closely comparable to the error measure for maze learning. The moves and time records include the measures for the first errorless trial. Except for the equivocal trial measure, Table I shows that the increase in difficulty is much more rapid than the increase in complexity. For the 3 move problem the errors, moves, and trials are so nearly the absolute minimum that there is little point in attempting to express the increase in difficulty from the 3 move to the 7 move problem as a function of the complexity. From the 7 move to the 15 move problem, however, the increase in number of errors is 10 times (75.3 ÷ 7.6), or 'as the cube' of the complexity ($7^3 = 343$; $15^3 = 3375$; $3375 \div 343 = 10$ approximately). With moves and time the increase in difficulty is slightly less rapid, but always considerably greater than the square of the fewest possible moves. Thus from the 7 to the 15 move problem the square of the minimum number of moves ($7^2 = 49$, $15^2 = 225$) would give an increase of about 4.6 times, whereas the actual ratios are 7.5 (182.7 ÷ 24.3) for moves and 6.0 (557.0 ÷ 93.5) for time.

It should be noted that although individual differences are

TABLE I

RELATION BETWEEN LENGTH AND DIFFICULTY OF DISC TRANSFER PROBLEMS; METHOD OF EQUATED GROUPS; TIME IN SECONDS

	Length of Problem		
	3 Move	7 Move	15 Move
Errors	0.3	7.6	75.3
Moves	3.5	24.3	182.7
Time	7.0	93.5	557.0
Trials	1.1	2.4	7.8

TABLE II

RELATION BETWEEN LENGTH AND DIFFICULTY OF DISC TRANSFER PROBLEMS; METHOD OF COUNTERBALANCED ORDER; TIME IN SECONDS

	Length of Problem		
	3 Move	7 Move	15 Move
	Simple to Complex		
Errors	0.3	16.0	88.4
Moves	3.7	41.9	218.5
Time	6.2	91.6	557.0
Trials	1.1	3.7	8.6
	Complex to Simple		
Errors	0.1	3.6	91.2
Moves	3.3	17.3	225.4
Time	3.4	26.2	540.0
Trials	1.05	1.9	9.0
	Average of Simple to Complex and Complex to Simple		
Errors	0.2	9.8	89.8
Moves	3.5	29.6	222.0
Time	4.8	58.9	548.5
Trials	1.1	2.8	8.8

large, the data are not of a nature to permit their satisfactory evaluation. In the nature of the case only one record could be obtained for a given subject, and one record on a problem of this kind is not a reliable index of individual ability.

Experiment II

Method of Counterbalanced Order

The second experiment to be reported was identical with Experiment I, except that only 58 subjects took part, and each subject did all three (2, 3, and 4 block) problems. Group IV (15 girls, 24 boys) solved the problems in the order (2–3–4), Group V (5 girls, 14 boys) in the order 4–3–2. The latter group is relatively small, but two considerations made it seem sufficiently large to ensure reliability equal to that of the remainder of the data. (1) The conditions under which Group III and Group V solved the 15 move problem were identical. The data from Group III in Experiment I thus furnished a check on the reliability of the results for the 15 move problem with Group V. The two groups together comprised 51 subjects, a sufficient number for moderately reliable results. (2) Preceding solution of the 15 move problem decreased the variability of Group V on the 7 move problem to such a degree that the probable error of the measures obtained is about the same as that presented by the data from the larger number of subjects (31) in Group II, Experiment I. The average number of moves (for example) required by the latter is slightly greater (17.3 ÷ 1.69) and by the former slightly less (24.3 ÷ 2.56) than ten times the $P.E._{av.}$

The averages of the several measures for Group IV and Group V and for the two groups combined appear in Table II, and in general confirm the findings of Experiment I. The composite data in the lower section of Table II show about the same difficulty ratios as were found for the first experiment. As before, interest centres in the difficulty increase from the 7 move to the 15 move problem. In Experiment I these were 10, 7, and 6 times for errors, moves, and time respectively. In Experiment II the corresponding ratios are approximately 9 (89.8 ÷ 9.0), 7.5 (222.0 ÷ 29.6), and 9.3 (548.5 ÷ 58.9). No great importance can be attached to the differences between the ratios found in the two experiments, since (as in all investigations of problem-solving) the data are almost certain to contain a few extreme cases that influence

the averages out of all proportion to their intrinsic significance. Thus the difference between the number of moves for solution of the 7 move problem in Experiment I (24.3), and the 7 move problem in the simple to complex order in Experiment II (41.9) is almost wholly due to three extreme cases in the latter group. When these are excluded the average becomes 24.8 instead of 41.9 moves.

A further reason for not stressing the differences between the average values for the two experiments is the evidence (discussed below) of a difference in transfer from simple to complex and complex to simple problems.

It has been noted above that the 19 subjects in Group IV did the 15 move problem under conditions identical with those for Group III in Experiment I, and the results of the two groups might have been combined into one average (for each measure) had it not seemed advisable to give some idea of the reliability of the data by presenting them separately. However, in estimating the reliability of the differences between the averages for the 7 move and 15 move problems all 51 subjects solving the 15 move problems should be considered (Group III and Group V). To illustrate this we may take the move measure. The average number of moves for Group III and Group V in the 15 move problem is 198.4 $\{(182.7 \times 32) + (225.4 \times 19)\} \div 51$. The $P.E._{av.\ 1}$ (of 198.4) is 14.6, and the $P.E._{av.\ 2}$ (of 24.3) is 2.56. The $P.E._{diff.}$ between the two averages is 14.8. The difference between the averages is $198.4 - 24.3$, or 174.1, which is more than 11 times its probable error.

Such a computation, however, tells us little of what we really need to know—whether the 'reliable' difference in difficulty is greater or less than the difference between the complexity of the two problems. However, some insight into the latter issue may be gained by another method. As a statistical measure, the probable error of an average signifies that (for example) the chances are 99.3 in 100 that the range of averages for the 7 move problem will be between $24.3 \pm 4\ P.E._{av.\ 2}$ (2.56), or between 13.0 and 34.5 moves, and that the range of averages on the 15 move problem will be 198.4

$\pm$ 4 P.E.$_{av.\ 1}$ (14.6), or between 140.0 and 256.8 moves. That is, the chances are 99.3 in 100 that the true increase in difficulty, as measured by number of moves, lies between 4 (140.0 ÷ 34.5) and 20 (256.8 ÷ 13.0) times.

One should have some hesitation, however, in placing too great reliance upon statistical measures as applied to our data. Reliability formulæ, in common with most statistical measures, assume that the distribution of individual scores follows the normal probability curve. In the present instance this assumption is not wholly justified. In fact, in the writer's experience it is exceptional for individual scores in problem solving to show a normal distribution. As our results indicate, they diverge from chance expectation in one and sometimes in two ways. (1) The distribution is skewed toward the upper values. A few subjects find the problem abnormally difficult. My impression (only offered as a guess) of the cause of this phenomenon is that most genuine problems have certain 'simple' features that almost all subjects grasp during the first few trials, but for which the penalties of oversight (in time and difficulty) are extraordinarily heavy. (2) The simpler problems are solved by some subjects in a single trial. Thus only rarely did a subject require more than one trial for the 3 move problem, and (for example) 10 of the 31 subjects in Group II solved the 7 move problem in a single trial.

The last named fact raises what might be considered an objection to our comparison of the difficulty of 'learning' the 3 move or 7 move problem, with the difficulty of learning the 15 move problem. If a subject solves a problem on the first trial, can we say that any learning has taken place? Should we not rather state that the problem is not a real problem for that subject? For the 3 move problem this objection is almost certainly valid. The task was evidently too simple to differentiate between the members of the group solving it; the occasional errors were plainly caused by a lapse of attention or some equally irrelevant influence. From our point of view, however, the 7 move problem constitutes a different situation. As far as one could judge from observation, it presented a genuine problem to all subjects. Those who solved it in one trial did so either after carefully surveying

the situation and (seemingly) working out the solution in advance, or by making a few 'chance' moves in the right direction, after which the problem cleared up. The former group should be credited with a genuine achievement, and the success of the latter must be balanced against the records of those who found the problem made more difficult by 'chance' initial moves in the wrong direction. In any case, no intermediate problem between the 7 move and the 15 move exists; and, further, an artificial lower limit to the range of individual differences would tend to obscure rather than to magnify the tremendously rapid increase in difficulty with increasing complexity.

Transfer

Since Group IV and Group V solved the problems in counterbalanced order of increasing or decreasing complexity, a comparison of their results might be expected to furnish data concerning the presence or absence of transfer from complex to simple and simple to complex problems. Here we may fairly disregard the 3 move problem, although its records show some slight transfer, because its simplicity makes it insusceptible to marked improvement and unlikely to aid in the solution of more difficult problems. For the 7 move and the 15 move problems, however, Table II shows clear evidence of transfer from complex to simple (15 to 7) but not from simple to complex (7 to 15). In regard to the latter, we note that the differences between Group III, Group IV, and Group V (Table I and Table II) on the 15 move problem are slight and unreliable. On the other hand, the 7 move problem following the 15 move problem is solved with fewer errors or moves, and with less time and trials, than is the case with Group IV, who worked in the 3–7–15 order, or Group II, who only attempted the 7 move problem. The time transfer is particularly striking. Group V required (on the average) only 26.2 seconds, as against 91.6 seconds and 93.5 seconds for Group IV and Group III.

Another fragment of evidence tending in the same direction comes from the fact that the correlation between scores on the 7 move and 15 move problems with Group V is $-.37$. For the 7 move and 15 move problems with Group IV, on the

other hand, the correlation is low but positive (.14). The latter value might simply mean that individual scores on these problems are unreliable, but taken in conjunction with the negative correlation for Group V, it seems more plausible to suppose that transfer 'spuriously' lowers the probability of a given individual achieving the same degree of success or failure (relative to the rest of the group) on both problems. Those who solve the more difficult problems first, or have more difficulty with a given problem, have more practice and thus a better chance to obtain and to stabilize an insight into the nature of the problem, and accordingly show greater transfer. Such a hypothesis would of course lead us to expect some slight transfer from simple to complex in addition to the evident transfer in the opposite direction. We have seen previously that there is no certain evidence of the former, but it is possible that simple to complex transfer exists, but is masked by inferiority in ability with Group IV. That Group IV was below average in ability might indeed be inferred from their error records on the 7 move problem, and from the facts previously mentioned that Group IV included three individuals who made abnormally poor records on the 7 move problem. However, the issue cannot be decided without further investigation.

Summary

The relation between complexity and difficulty of solving the disc transfer problem was investigated by the method of equated groups and again by the method of counterbalanced order. The data from the two experiments agree, although the results of the method of counterbalanced order are partly invalidated by greater transfer from complex to simple than from simple to complex. The 3 move problem was solved in nearly the minimum number of moves or trials. From the 7 move to the 15 move problem the increase in number of errors was 10 times (Experiment I) and 9 times (Experiment II), or approximately the cube of the complexity. Moves and time showed slightly smaller increases: 7 and 6 times in Experiment I and 7.3 times and 9.3 times in Experiment II.

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WORDS AS 'GESTALTEN'

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Words have often been cited as examples *par excellence* of configurations. Words, then, which convey meaning should resist rearrangement into other words, more strongly than the forms in which the letters are merely jumbled. H. L. Hollingsworth [1] has performed an experiment in which he endeavored to ascertain the amount of resistance to such rearrangement, if any. He concludes in general that words do not resist such rearrangement. However his conclusions seem somewhat at variance with the general trend of data shown in his tables. This suggests that more work might well be carried out on this topic to clear up these seeming discrepancies.

In the main experiment, Dr. Hollingsworth used two forms of tests, C and D. The form D was apparently 'more difficult than form C.' The tests constructed were the 'configured' and 'unconfigured' arrangements of letters which appeared alternately. His results appear as follows:

AVERAGE NUMBER OF WORDS BUILT

		'Configured'	'Unconfigured'
Form C.....	73 cases	5·4	5·7
Form D.....	79 cases	3·7	4·5
Form C.....	42 cases	4·7	2·9

An examination of the above table will disclose the fact that with the first two groups more words were made from the 'unconfigured' than from the 'configured' matter. This is reversed with the third group. It will be noted, however, that the first two groups were much larger than the third.

[1] The conditions of verbal configuration, J. EXPER. PSYCHOL., 18, 299–306, 1935.

The conclusions reached seem premature in view of this consideration.

However it is stated that "one arrangement of letters is just as much of a 'configuration' as is any other, in spite of the fact that a naïve person may feel that letters somehow 'look more like a unit' than do letters that make nonsense. . . . Tachistoscopic studies long ago demonstrated that words do not function as 'gestalten.' . . . Words, we have concluded, are not 'gestalten.' But they come as near being this as does anything else."

The explanation given for the 'patching out' of words does not completely satisfy one who has no preconceived theories. Whether or not words are 'gestalten' is not the primary purpose of the present study. The question is still unanswered, will one type of arrangement be built as easily as another, and will the 'meaningful' ('configured') or 'meaningless' ('unconfigured') of the arrangement of letters influence the number of errors and omissions?

The purpsse then is to study the number of errors (omissions also being counted as errors) in building words with letters of 'meaningful' and 'meaningless' arrangement. Incidently we have studied the relation of intelligence to the number of 'configured' errors.

General Procedure

Ten words of each of these three classifications were chosen as follows:

Form A. Names of birds
Form B. Names of cities
Form C. Psychological terms.

From each noun an arrangement of 'meaningful' and 'meaningless' forms were made and assembled as illustrated:

Form A

Group I	Group II	Key:
in gale night	nitigahglne	(nightingale)
marlald	doll arm	(mallard)
wall sow	slawlow	(swallow)

This material was presented to 111 students in General Psychology for 10 minutes. The directions read:

"Opposite each disarranged word write the correct response, using all the letters given and no more. Do as many as you can. If some are difficult pass over them and come back if you have the time.

"These are all nouns, with the letters disarranged. Thus of RIB DERYL you would write LYRE BIRD, and of SWBRONID, SNOW BIRD."

The errors were checked and differences and probable errors of differences were computed. These data are given in Table 1. It will be noted that our tables deal with the num-

TABLE 1.

COMPARISON OF MEANS, PROBABLE ERRORS OF DISTRIBUTION, PROBABLE ERROR MEANS, DIFFERENCE OF MEANS AND PROBABLE ERROR DIFFERENCES IN THE 'MEANINGFUL' AND 'MEANINGLESS' ARRANGEMENT OF NOUNS OF BIRDS, CITIES AND PSYCHOLOGICAL TERMS

No. of cases: 111	A (birds)		B (cities)		C (psy. terms)	
	M	L	M	L	M	L
Mean of errors	1.216	.864	1.410	.666	3.837	1.540
P.E. dist	.607	.569	.783	.551	.904	.988
P.E. mean	.057	.054	.074	.052	.086	.094
Diff. of means	.352		.744		2.297	
P.E. diff	.078		.085		.040	

M—Meaningful errors. L—Meaningless errors.

ber of errors while Hollingsworth dealt with the number of words built. Consequently in our tables a low score represents a large number of words constructed, whereas in his tables a low score represents a small number constructed.

Intelligence scores are from the Otis Self-Administering Test, Form D, which was administered in their freshman year.

RESULTS

Under the assumption that as the psychological terms were more difficult to build, a greater amount of intelligence might be required to form new words and this would be more nearly parallel to a group of high school students building the nouns for birds or cities. The following correlations were made

between final grades in general psychology and meaningful errors, + .061 ± .064; raw scores from intelligence tests, and meaningless errors, − .079 ± .069; and raw scores from intelligence tests, and meaningful errors, + .023 ± .070.

Conclusions

An examination of the above shown table indicates that in every case there are more errors in building words from meaningful material than from meaningless forms. Therefore more 'unconfigured' forms were built into words than 'configured' ones. The difference of means .352 ± .078 for A; .744 ± .085 for form B; and 2.297 ± .040 for C are all statistically reliable. In every instance the difference of the mean is at least four times larger than the probable error of the difference. This seems to be in general agreement with the findings of Hollingsworth, with the exception of the 42 cases on the easiest form; yet his conclusions are at variance with his first results.

Also in harmony with the work of Hollingsworth, we find no correlation between intelligence and the ability to build words. He has suggested that there might be positive results with dull or younger students. In elevating the difficulty of the words to be built, while the intelligence level remains unchanged, we are justified in assuming that this more nearly approximates the dull or younger group.

In view of these findings we are able to reopen the question which Dr. Hollingsworth had endeavored to close. 'Configured' forms convey meaning and resist being changed into other words with greater tenacity than do meaningless arrangements. This is as true for the brilliant student as with the duller one. We might safely agree with Hollingsworth's statements, which we take out of its setting, that "the college student resembles the ape, the infant, and the idiot" in at least one respect.

The writer is greatly indebted to Dr. C. W. Telford for suggestions and criticisms in this study.

A 'MULTITESTER' AND 'PORTABLE POLYGRAPH'

TWO NEW INSTRUMENTS COMBINING ACCURACY, PORTABILITY AND FLEXIBILITY, FOR SECURING OBJECTIVE DATA IN LEARNING EXPERIMENTS[1]

BY J. J. RAY

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For some time the writer has been interested in psychological apparatus for use in experiments in learning at the higher levels. This interest led him to construct a mechanical device[2] for administering the Peterson Rational Learning Problem[3] during the summer of 1932. The further study of problems in this field has led to the design and construction of two new instruments that will be described in this paper. The specific problem for which these two instruments were designed was an investigation of the generalizing ability of children of different intellectual capacities. Two conditions of this investigation seemed to demand the use of apparatus. First, some means for securing a uniform presentation of learning material was desired. Second, objective records of the subjects were desired. The device designed by Pressey[4] was an approach to the type of instrument considered necessary to meet the former condition in that it allowed a variety of material to be presented to subjects and the presentation was uniform for each. Some type of polygraph would serve to meet the latter need. However, after a brief consideration, the Pressey instrument was found not to be adaptable to the writer's needs and as an additional problem, all available

[1] These two instruments were on display at the Instrument Exhibit of the American Psychological Association in Ann Arbor, Michigan, September 1935.

[2] Unpublished Master's thesis, "*Constructive Activity as a Process in Learning*," Peabody College, August, 1934. Also described in a paper presented at the 30th Annual meeting of the Southern Society for Philosophy and Psychology, Nashville, Tennessee, April 19, 1935.

[3] Peterson, Joseph., Experiments in rational learning, *Psychol. Rev.*, 1918, **25**.

[4] Pressey, S. L., *Sch. and Soc.*, 1926, **23**, No. 586.

polygraphs were too complicated, cumbersome and not easily portable. Because of these difficulties, two new instruments, a Multitester and Portable Polygraph, were designed and constructed to meet the conditions of the contemplated investigation.

The Multitester

The Multitester is so called because it has a variety of uses. It is a small instrument weighing eight and one-half pounds and may be placed on a desk or table and used in about the same way as an ordinary typewriter. (See Plate I.)

In essence the Multitester is a portable device for controlling the presentation of any series of twenty paired stimuli (*s*) of prepared problems made in the form of paper tapes and applied to a rotating drum. The individual units of any particular problem such as miniature pictures, characters, nonsense syllables, numbers or words, appear in sequence through a small aperture or window (*a*) in the front of the instrument. By means of two response keys (*k*) the subject attempts to select the 'correct' one in each of the series of twenty paired stimuli. Pressing the key on the side of the predetermined or coded work, nonsense syllable, picture, word or design causes a small green light (*g*) to flash and also rotates the drum supporting the tape one twentieth of a revolution, thus exposing the next pair of stimuli. These two facts, green light and partial rotation of the drum, indicate 'correct choice' to a subject. Conversely, if the subject presses the key on the side of the syllable, picture, word or design that is on the side *opposite* the coded one, then a small red light flashes (*r*) and the drum does *not* rotate, indicating to the subject, 'incorrect choice.' Repeated operation of this 'incorrect' response key will bring repeated red flashes and the drum will remain stationary. The subject in this dilemma must press the 'correct' key. Thus the subject faces each unit of any problem until he presses *the* key which will secure a 'correct' response.

In all of the various problem situations the subject continues his trials until he learns to press the keys in the sequence that will produce a series of twenty correct responses, or twenty successive green light flashes without any red light flashes. This situation immediately suggests the use of this instrument as a device for the presentation of mental maze problems, where no problem tapes would be used on the drum.

Great flexibility in the use of this machine may be secured by increasing the variety of the detachable problem tapes. The writer is now using a battery of twenty-five problems or a series of twenty-five different tapes. By using an especially designed stencil these blank paper strips may be cut to the proper length, marked for location of the twenty problem units and then easily completed by typewriter, or by pasting pictures or by drawing original designs by hand.

The conditions surrounding the learning of a problem with this device may be varied. A problem may be learned with the lights removed, or the window may be closed and the lights left in position. These changes do not in any way modify the mechanical operation of the device. These factors suggest many possible variations in a study of the conditions influencing maze learning, or in fact of any learning situation.

The variety of problem settings or of maze possibilities is limited only by the fact that the drum has twenty segments. Regular alternation mazes of several kinds may be set up on the instrument by arranging the drum actuating pins in any of the following suggested sequences:

Single alternation, R–L–R–L–R–L ··· to 20 places.
Double alternation, RR–LL–RR–LL ···
Quadruple alternation, RRRR–LLLL–RRRR ···
Quintuple alternation, RRRRR–LLLLL ···

Regular progression mazes may also be presented, such as;

R–L–R–LL–R–LLL ··· to 20 places.
R–L–RR–LL–RRR–LLL ···

Regular regression mazes, the reverse of the two immediately above would be:

LLLLL–R–LLLL–R–LLL ··· to 20 places.
LLLL–RRRR–LLL–RRR ···

The following are samples of irregular alternation mazes:

RL–LR–RL–LR ··· to 20 places.
RLLR–RLLR– ···

Regular unequal alternation is also suggested;

R–LLL–R–LLL ··· to 20 places.
RR–LLL–RR–LLL ···

An almost endless variety of random mazes is possible, one that has been used a great deal in experimentation with this device is:

R–L–RR–LL–RR–LLL–RR–LL–R–L–RR–L.

This instrument may also be used as a portable tachistoscope. The material to be presented is mounted on the rotary drum in the form of a prepared problem tape, and the experimenter sets the instrument so that operation is accomplished with one key only. This may be either the right or the left key, whichever is easiest or more convenient for the experimenter. This key may then be operated manually at regular interval controlled by metronome or stop watch. For association tests the window or aperture can be half closed to conceal either the right or the left half of any problem material contained on a mounted tape.

Mechanism

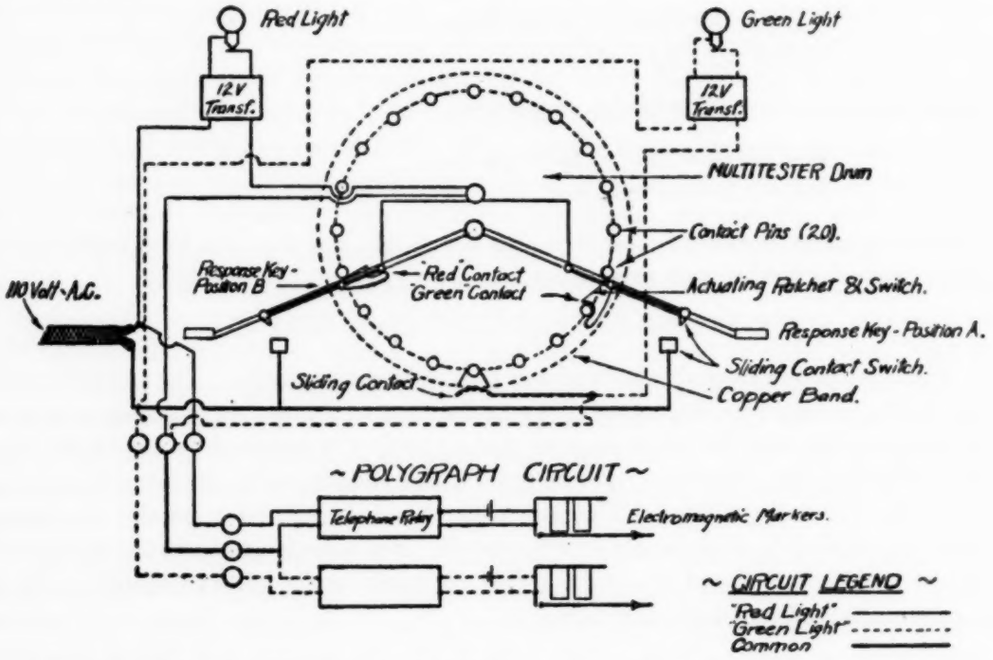
The heart of the device is the hard rubber drum made of laminations of sheet rubber and two discarded Radiola radio tuning dials as covers. The drum is 5½ inches in diameter with a 2 inch face. It is upon this drum that the various problem tapes are mounted.

At 20 equally distant points on a circle described on the side of this drum 20 brass pins (see wiring diagram), ⅛ of an inch in diameter and 2⅜ inches long are inserted, perpendicular to the side of the drum. The pins are movable in this mounting. As they are ⅜ of an inch longer than the thickness of the drum they necessarily protrude on one side of the drum ⅜ of an inch when pressed flush with the face on the opposite side.

To alter the pattern of a maze, or to change the required responses from a negative to a positive or vice versa, the procedure is very simple. The experimenter has merely to raise the hinged portion of the rear part of the cabinet (*d*) and press the brass pins projecting from the drum either to the right or to the left according to the place he wants each successive green light or 'right response' to be located. If all of the pins are

pushed to the right, then the right key alone will actuate the drum, if all of the pins are pushed to the left, then only the left key would actuate the drum and so on. By varying the positions of the projecting pins the experimenter determines the number and location of correct responses. It is impossible to set the instrument so that both keys will actuate the drum at any one point, unless longer pins are inserted. This suggests a very difficult problem, namely, a maze where certain keys would produce a correct response only when pressed in an exact sequence but with several keys that would show correct response with *either* key. The problem here would be to locate exactly the position of the single keys in the shortest possible time. This and other bizarre uses of the device are suggested only to show the variety of settings possible.

When the Multitester is used as a maze no problem tape need be applied to the surface of the drum unless an indication of the serial position is desired. In the latter case a tape numbered from 1 to 20 would be used.



Wiring diagram—multitester. Showing 'red' and 'green' circuits-connection to polygraph.

The drum is mounted on a ¼ inch shaft which is in turn supported by two inverted V shaped brackets upon which adjustable bearings are mounted. This shaft extends through the sides of the cabinet on both the right and left sides. On the terminus of the shaft at the right, a knob is affixed for manual operation of the drum (necessary in the changing of combinations and in affixing problem tapes). On the left terminus of the shaft is a small pointer or indicator (*i*) which rotates with the drum. The twenty white numbers (*n*) stamped in the side of the cabinet correspond to the relative position on the drum of the twenty stimuli of a problem. Thus, during experimentation, the experimenter can determine at a glance the location of a subject in whatever problem he is working. As this indicator is adjustable by loosening a set screw (*w*), it serves a useful purpose in making new settings of the drum possible without changing the basic combination. Any number in the series may become the *new* number 1 (the new starting point) by the simple process of changing the position indicator to that particular number.

The tapes upon which problems are written or mounted are of uniform size, 17 inches long and 2 inches wide. These problem tapes may be attached or removed from the drum in about 10 seconds. To apply a tape the experimenter lifts the hinged rear portion of the cabinet (*d*), turns the manual control knob (on the right side of the instrument) until the indicator shows number 10, or until the open section on the surface of the drum appears. At this point two celluloid ribbons, the same width as the drum, will be seen to be permanently attached to the outer surface. The problem tape is placed between these two transparent ribbons, then held loosely with the left hand. With the right hand operating the manual control knob, the drum is again turned a complete revolution. This action 'winds on' the tape. The tape, being the same length as the circumference of the drum will completely encircle it. By a simple interlocking joint the celluloid ribbons are pinned to the drum and the tape is ready for presentation to the subject when the drum is rotated until the indicator points to 1. The first pair of stimuli will now appear through the front window.

A knob on the right side of the cabinet located below the manual control knob is the control of the friction brake on the drum. By loosening or tightening this knob the force necessary to operate the response keys is regulated. It is the substitute for the 'touch control' of the modern typewriter.

This device is so constructed that pressing the response keys not only actuates the drum through a ratchet mechanism attached to each key but these ratchets also serve as multiple switches (see wiring diagram). Four electrical circuits may be closed by the key action at any particular point, depending upon the position of the contact pins. The four electrical circuits eminating from the key switches are; (1) a circuit through a 12 volt transformer which furnishes current for the small 12 volt green lamp used as a signal light for the subject, (2) another circuit similar to the first through a second 12 volt transformer for the energizing of the small 12 volt red signal lamp, (3 and 4) two branch circuits terminating in binding posts outside the cabinet which are parallel in function to the first two circuits except that these two carry 110 volts and terminate in binding posts and do not pass through transformers. These two circuits are for connection with a signal marker or polygraph (indicated in wiring diagram).

The operation is simple if 110 volt A.C. is available. If connected with an outlet, then, pressure on a response key will always make one of two possible electrical connections. If a contact pin is projecting on the right, let us say, pressure on the right key (in position *A*) will move the drum because the ratchet will engage this pin and the drum will move with the key. The key through this ratchet will also close two circuits, one to the green light and one to the external binding posts which if connected with an electric marker would record the response on a tape. If the opposite key (in position *B*) had been pressed, two different circuits would have been closed, one to the red light and one through other binding posts which may be connected to a second electric marker for the recording of errors. In the recent use of this instrument it has been connected with the portable polygraph to be described later.

In order to evade the possibility of a subject attempting to 'feel the keys,' that is, pressing gently on the key so that engagement of the ratchet with the contact pins could be ascertained in advance, the switches were designed to make contacts, either green or red circuit, *before* the ratchet engaged the pin. The key has only to be depressed about ¼ of an inch before contact is made with one or the other of the two possible circuit combinations.

For the convenience of obtaining records of successes and errors when electrical operation is not convenient or desirable, a small Veeder counter is mounted at the rear.

On it are recorded total key depressions during a trial or during a problem. It may be reset to 0 at any time. This counter also makes possible a check on results when an electrically operated counter is used.

The Portable Polygraph

The chief difficulty with most present laboratory recording apparatus is lack of compactness and of easy portability. Since the writer desired accurate results from experiments to be performed in a variety of locations, portability was an absolute necessity in any recorder. In addition to portability and accuracy this device ought to use easily obtained supplies in the way of paper, ink and pens. The experimental situation required a record of four different factors, errors, successes, time and number of trials. Accordingly, the polygraph (Plate I) was designed with these requirements in view. As now constructed, the entire instrument is mounted in a cabinet 15 inches long, 7 inches wide and 6 inches high and weighs 12 pounds. For operation the only electrical connections are: (1) plug into a 110 volt A.C. house lighting circuit, and (2) connect the three binding posts with whatever instrument has been selected for interrupting or making electrical connections, the frequency of which it is desired to record. The instrument in actual use applies three inked lines to a synchronously moving tape. One pen is used to record successes, one to record errors and the third to apply a time scale in various fractions of a second.

Construction

The essential elements of this polygraph are (1) a Warren Telechron synchronous motor, Model C-2, for driving the tape, (2) a gang of three electric markers (*m*), (3) a spool of adding machine tape (*t*) mounted in such a manner that in unwinding it passes beneath the electric markers, (4) a second small Telechron Motor (*T*), Model B-3, which is used to close a circuit at selective intervals of either ½ or 1 second (control of the interval is by a rheostat type switch (*sw*), (5) a pair of telephone relays (*r*) which transfer the 110 volt A.C. current of the Multitester to D.C. necessary for operating the electric markers, (6) three small dry cells for energizing the three electric markers.

The large C-2 Telechron Motor pulls the one inch wide adding machine tape over a small copper writing platform (*P*) by means of a rubber covered roller attached to the drive shaft. A weighted roll with flanges rests above this drive roll and furnishes sufficient contact for pulling the tape. The speed of this tape is approximately .25 inches per second. Three channels in the upper weighted roll allow the freshly inked lines on the tape to pass through the rolls without smudging or blurring.

The 6¼ inch by 2½ inch writing platform over which the tape travels after it leaves the pens was designed in order to allow the experimenter to add written notations to the tape during the process of any experiment. In actual use this has proved to be a very valuable feature.

A variable spring tension (*s*) at the end of the shaft upon which the spool of tape is mounted allows for control of the amount of freedom given to the unwinding spool during operation.

As the impulses coming from the Multitester used in the experiment for which this polygraph was designed are 110 volts A.C., this made the installation of relays necessary in order to shift from 110 volt A.C. to D.C. Accordingly two telephone relays were built in as an integral part of the polygraph. The markers may of course, be operated by impulses of current direct from battery circuits, and the relays are not necessary

when the apparatus with which it is connected can make interruptions in these circuits directly. Three dry cells, the kind used in ordinary flashlights, are used to energize the three electric markers.

Another feature of this polygraph is the separate synchronous motor that is used to make the interruptions in current that are the basis of the time scale. This motor operates two spring contact switches, one making a contact every second, the other making a contact every half second. These two switches are in circuit with one of the markers and by using one or the other of these circuits, controlled by a rheostat switch, a time scale is applied to the traveling tape in either second or half second intervals. By using different motors of different gear ratios these intervals may be varied—for example, 5, 10, or 15 second intervals.

Separate control switches are provided for the two motors. Both are mounted on the panel (*s*1), (*s*2) in easy reach of the experimenter. The rheostat switch controlling the intervals of the time marker is conveniently located directly under the two motor switches. Three points provide 'off,' '½ sec,' and '1 sec.'

A small door (*d*) on the left front panel allows adjustment of the relays, and a glass window in the center of the front panel allows observation of the polygraph with the cabinet closed.

The current for the operation of both motors is taken from a single receptacle in the cabinet and this is easily plugged into by means of an extension cord to any outlet or light socket. Connection to the two Multitester circuits is through three external binding posts, one of which is common to both circuits.

The problem of supplies is simplified by using 1⅛ inch commercial adding machine tape which can be purchased for 10 cents a roll. The ink used is a solution of 3 parts Carter's fountain pen ink and 1 part glycerin. The pens or markers (*m*) are made from discarded hypodermic needles, the needles being broken off near the base and smoothed with emery cloth. The hollow base of the needle holds about six drops of ink and this will last approximately 30 minutes of operating time before a refill with a medicine dropper is necessary.

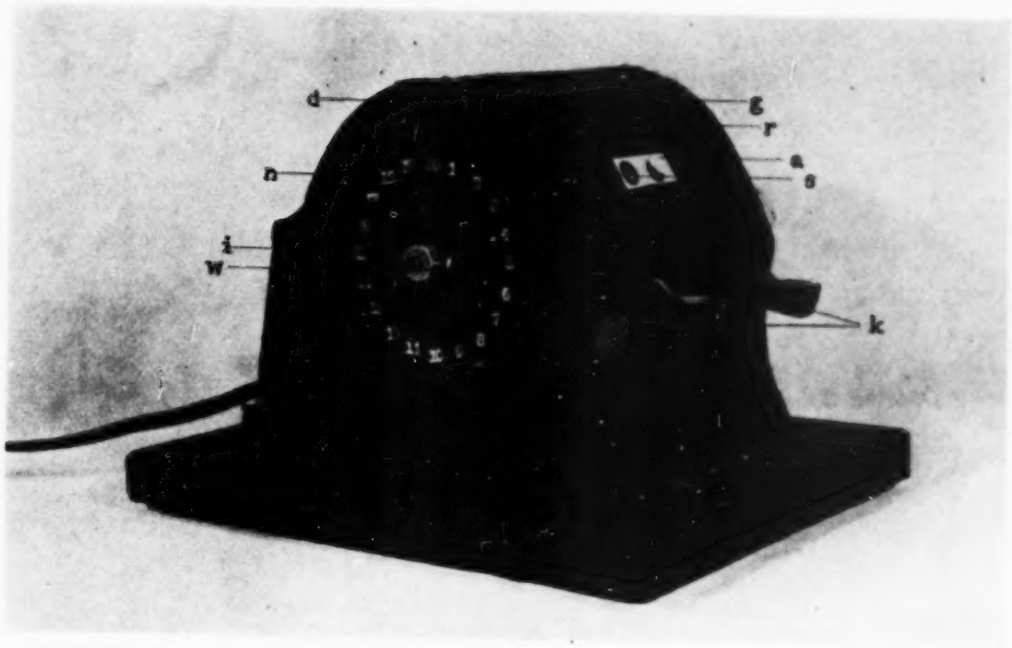
When used in the field the writer has learned to carry an extra battery, an extra roll of tape and a small sample ink bottle full of writing fluid at all times. There is ample room in the cabinet for all of these supplies.

These two devices, the Multitester and the Portable Polygraph, have been used in experimental work rather steadily for a period of three months and the results obtained have been very satisfactory.

(Manuscript received June 19, 1936)

PLATE I

Multitester

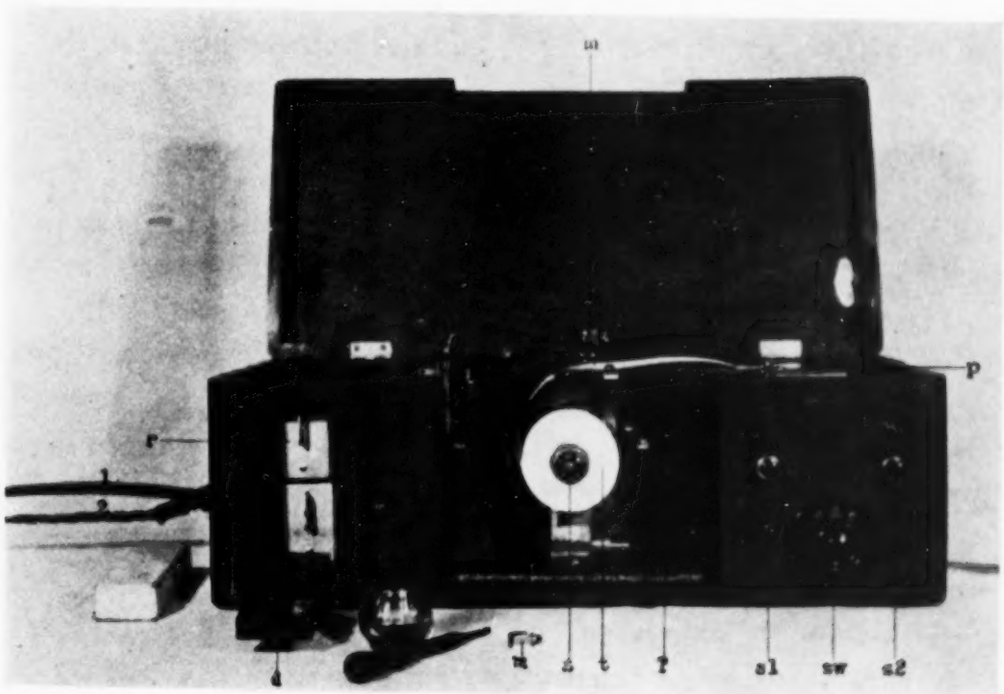


Aperture (*a*)
Keys (*k*)
Stimuli (*s*)

Green light (*g*)
Red light (*r*)
Hinged door (*d*)

Indicator (*i*)
Numbers (*n*)
Adj. set screw (*w*)

Polygraph



Connections (1), (2)
Markers (*m*)
Tape (*t*)
Motor (*T*)

Switch (*sw*)
Relays (*r*)
Platform (*p*)

Spring (*s*)
Motor switches (*s*1), (*s*2)
Door (*d*)